FORTY-SECOND ANNUAL REPORT

OF THE

NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION

CONDUCTED JOINTLY BY THE

North Carolina Department of Agriculture

AND THE

North Carolina State College of Agriculture and Engineering

FOR THE

YEAR ENDED JUNE 30, 1919

INCLUDING BULLETINS Nos. 239 AND 241, AND TECHNICAL BULLETINS Nos. 15 AND 16

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LETTER OF SUBMITTAL

Raleigh, N. C., June 30, 1919.

To His Excellency, T. W. Bickett,
Governor of North Carolina.

Sir:—I have the honor to submit herewith report of the operations of the Agricultural Experiment Station, conducted jointly by the North Carolina Department of Agriculture and the North Carolina State College of Agriculture and Engineering, for the year ended June 30, 1919. This work is under the immediate direction of the "Joint Committee for Agricultural Work," provided for in chapter 68 of the Public Laws of 1913, and amended by chapter 223 of the Public Laws of 1917, and the report is made in accordance with the requirements of the act of Congress approved March 2, 1887, and known as the Hatch Act.

Very respectfully,
B. W. Kilgore,
Director.

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S. G. Rubinow	Assistant to Director, Extension Service
F. H. Jeter	Agricultural Editor
A. F. Bowen	Bursar
Miss S. D. Jones	Bursar
Miss Mary S. Birdsong	Secretary to Director
H. C. Evans	Auditor and Executive Assistant

AGRONOMY

C. B. Williams	Chief in Agronomy
J. K. Plummer	Soil Chemist
W. F. Pate	Agronomist, Soils
E. C. Blair	Assistant Agronomist, Soils
S. K. Jackson	Assistant Agronomist, Soils
R. Y. Winters	Plant Breeding
V. R. Herman	Assistant in Plant Breeding
G. M. Garren	Assistant in Plant Breeding
S. J. Kirby	Assistant in Plant Breeding
†M. W. Hensel	Specialist in Sugar Plant Production
†W. E. Hearn	Soil Survey
†S. O. Perkins	Assistant in Soil Survey
L. L. Brinkley	Assistant in Soil Survey
†E. S. Vanetta	Assistant in Soil Survey
S. F. Davidson	Assistant in Soil Survey
†R. C. Jurney	Assistant in Soil Survey
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E. H. Matthewson	Tobacco Expert
A. R. Russell	Assistant in Field Experiments

CHEMISTRY

W. A. Withers	Chemist	E. S. Dewar	Assistant Chemist
F. W. Sherwood	Assistant Chemist	R. A. Fetzer	Assistant Chemist
J. M. Pickel	Feed Chemist	G. L. Arthur	Assistant Chemist
W. G. Haywood	Fertilizer Chemist		

ENTOMOLOGY

Franklin Sherman, Jr.	Chief in Entomology
Z. P. Metcalf	Entomologist
R. W. Leiby	Assistant Entomologist
J. E. Eckert	Assistant Entomologist
†C. L. Sams	Beekeeping
†M. R. Smith	Extension Entomologist

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C. D. Matthews	Acting Chief, Division of Horticulture
J. P. Pillsbury	Horticulturist
L. R. Detjen	Assistant Horticulturist
L. H. Nelson	Assistant Horticulturist
J. M. Dyer	Assistant Horticulturist
P. T. Schooley	Extension Horticulturist

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R. S. CURTIS	Associate in Animal Industry
STANLEY COMBS	Dairy Experimenter
B. F. KAUPP	Poultry Investigator and Pathologist
†J. A. AREY	Dairy Farming
†W. W. SHAY	Swine Extension
†A. G. OLIVER	Poultry Extension
JOHN E. IVEY	Assistant, Poultry Investigations
E. C. WARDEN	Assistant, Poultry Investigations
†F. R. FARNHAM	Assistant in Dairy Farming
†A. C. KIMREY	Assistant in Dairy Farming
†D. R. NOLAND	Assistant in Dairy Farming
E. C. BRINTNALL	Assistant in Dairy Farming
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†J. W. SLOSS	Assistant in Beef Cattle
EARL HOSTETLER	Assistant in Beef Cattle and Swine
†GEORGE EVANS	Assistant in Sheep

PLANT PATHOLOGY

F. A. WOLF	Plant Pathologist
R. A. JEHLE	Extension Pathologist
S. G. LEHMAN	Assistant in Bacteriology

DRAINAGE

†H. M. LYNDE	Senior Drainage Engineer
F. O. BARTEL	Junior Drainage Engineer

VETERINARY

W. C. REEDER	Veterinarian

MARKETS AND RURAL ORGANIZATION

†W. R. CAMP	Chief, Division of Markets
†O. J. MCCONNELL	Assistant in Cotton Grading and Marketing
†CHAS. S. JONES	Specialist in Livestock Marketing
GORRELL SHUMAKER	Assistant in Marketing Fruits and Vegetables
BOLLING HALL	Assistant in Marketing Fruits and Vegetables

FARM MANAGEMENT

†J. M. JOHNSON	Farm Management

BRANCH STATIONS

R. W. COLLETT	Assistant Director, in Charge Branch Stations
F. T. MEACHAM	Assistant Director, Iredell Branch Station
C. E. CLARK	Assistant Director, Edgecombe Branch Station
E. G. MOSS	Assistant Director, Granville Branch Station
S. C. CLAPP	Assistant Director, Buncombe Branch Station
A. S. CLINE	Assistant Director, Washington Branch Station

FARM DEMONSTRATION WORK

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H. H. B. MASK	Assistant State Agent
E. S. MILLSAPS	District Agent, Western District
T. D. MCLEAN	District Agent, Central District
J. M. GRAY	District Agent, Mountain District
O. F. MCCRARY	District Agent, Northeastern District
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HOME DEMONSTRATION WORK

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MISS LAURA M. WINGFIELD	Assistant State Home Demonstration Agent
MRS. J. H. HENLEY	District Agent, Western District
MRS. ESTELLE T. SMITH	District Agent, East Central District
MISS MAUDE E. WALLACE	District Agent, West Central District
MRS. CORNELIA C. MORRIS	District Agent, Central District

FARM FORESTRY

H. B. KRAUSZ	Farm Forestry Specialist
J. WULFF	Assistant Farm Forestry Specialist

FARM MACHINERY

E. R. RANEY	Farm Machinery Specialist

The members marked with * are members of the Joint Committee for Agricultural Work, and the Station is under their direction.

†In cooperation with the U. S. Department of Agriculture.

Forty-Second Annual Report of the North Carolina Agricultural Experiment Station

FOR THE

YEAR ENDING JUNE 30, 1919

B. W. Kilgore, *Director.*
F. H. Jeter, *Agricultural Editor.*

The Forty-Second Annual Report of the North Carolina Agricultural Experiment Station covers the time of the closing of the great war, and the period of adjustment and reconstruction immediately following. Because of this, it has been necessary to make some rearrangements in the activities in which the workers are engaged, as well as to cope with conditions which naturally follow such a period of stress and unusual activity.

One of the great things to which the workers have been called upon to adjust themselves has been increased living costs, and a certain amount of unrest due to this reconstruction era. A number of the workers have returned from active war service, and are now busily engaged in their peace-time occupations. Many of them have found it somewhat hard to effect a complete adjustment to pre-war conditions. However, the Station staff as a whole has conscientiously carried forward all the problems in which it is engaged in rendering service to the agricultural interest of the State.

Due to the discontinuance of the emergency appropriations from the Federal Department of Agriculture, it has been necessary to release some few workers, and, therefore, to curtail activities in some directions. This has not seriously hampered the activities as a whole, and all the main problems which were being investigated are being carried along in a satisfactory manner.

The past year has been an unusual one for agriculture in the State. In the first place, weather conditions have made it a poor crop year. In spite of this, the total value of the crops has been considerably increased, and during the year the statistics show that North Carolina has come to be the fourth ranking State in the Union in total value of crops produced, amounting in value to $683,168,000. This has been largely due to the good prices prevailing for tobacco and cotton.

The State has also suffered from several outbreaks or epidemics of insects, notably that of the green clover worm in eastern North Carolina, and the fall army worm in several different sections. The latter part of the year 1919 also saw the first invasion of the State by the cotton boll weevil, it being found in parts of Columbia, Brunswick, New Hanover, and Robeson counties.

Good progress has been made on practically all of the projects now being studied by the different divisions. In addition to its regular work, the Division of Markets has been called upon to take charge of and and administer the cotton warehouse law passed by the Legislature of 1919, and put under the supervision of the State Department of Agriculture. Under the coöperative arrangement between the State Department of Agriculture and the State College of Agriculture, by which the Experiment Station is conducted, this activity was turned over to the Division of Markets and handled first by Mr. O. J. McConnell, later by Mr. W. R. Camp, Chief of the Division.

The past year has also been a great fair year in North Carolina. State aid has been extended to over 275 community, county, and district fairs, and the Experiment Station and Extension workers have been called upon to assist local men and women in the judging and handling of their fair exhibits. Practically all of the fairs have had a most successful season, and many of them are doing much to stimulate competition in producing better crops and livestock. An effort has been made to keep these fairs as educational in their nature as possible. In this way, a great opportunity has been given to foster improved methods of agriculture throughout the State.

As heretofore, the Station has continued its policy of existing only for the good of the farmers of the State, and in rendering service to North Carolina. Possibly never before has it enjoyed such a demand for its services. This is seen in the calls made on the workers for personal assistance, and in the great number of letters coming in from farmers and others requesting information on the problems confronting them. During one two-weeks period, when a careful count was made of the requests for publications, it was found that 973 separate letters and cards had been received.

The Station issued only two bulletins during the year, one being No. 239, on "The Tobacco Flea Beetle," and the other No. 241, on "Soybeans and Cowpeas for North Carolina." Two technical bulletins, the first being No. 15, "A Monograph on Trembles or Milk Sickness, and White Snake Root," and No. 16, "Clover Stem Rot," were also issued and distributed.

CHANGES IN STAFF

The changes in staff have been mostly with those members of the Agricultural Extension Service who were employed under emergency funds. However, a number of changes have also been made among the investigational workers.

During the year, Mr. W. R. Camp resigned as Chief of the Division of Markets to accept a position with the University of California.

Mr. W. W. Garnett, Assistant Superintendent of Credit Unions, resigned to go into similar work in Georgia, and Mr. O. J. McConnell resigned as superintendent of warehouses to go into commercial cotton brokerage work within the State.

Mr. A. J. Reed resigned as head of the dairy farming office, of the Animal Industry Division, to go into industrial creamery work in Raleigh, being succeeded by Mr. J. A. Arey, formerly county agent in Iredell County. Messrs. A. C. Kimrey and E. C. Brintnall were added to the dairy farming office during the same time to fill vacancies existing for some time.

In the Horticultural Division, Mr. C. D. Matthews has continued Acting Chief of the Division of Horticulture, being assisted by Messrs. L. H. Nelson, J. M. Dyer, and P. T. Schooley, who were secured during the latter part of 1919 to carry on the investigational and extension work of this Division.

Dr. G. A. Roberts resigned as Veterinarian to take up work in Brazil with the Rockefeller Foundation. He was succeeded by Dr. W. C. Reeder, assistant in his office. For the present, Dr. Reeder has devoted practically all of his time to college work.

W. J. Brockington resigned as Superintendent of the Trucking Branch Station in Pender County to return to county agent work, with headquarters at Fayetteville, in Cumberland County. For the present, Mr. R. W. Collett has had direct management of this branch station, as well as the general supervision of the other stations of the State.

Dr. J. K. Plummer, Soil Chemist, returned from a leave of absence during which time he was engaged in chemical research work for the War Department, and was elected State Chemist, succeeding Mr. B. W. Kilgore, who gave up this work to devote his entire time to the administration of the experimental and extension activities.

INTERESTING RESULTS SECURED

As quickly as certain truths have been determined by research work, these have been given to the people of the State by means of special articles in the Extension Farm News, and through a special service to the newspapers. In a similar way announcement has been made of all available publications issued. In this way the results of experimental work have been widely disseminated. In the same way the Agricultural Extension Service workers have taken the findings of the investigators and carried them direct to the people in the field.

This was strikingly shown during the year with the investigations being conducted on the muscadine type of grape at the Trucking Branch Station. Through several years of research work, done in coöperation with the Bureau of Plant Industry, the Station has determined that certain of the muscadine types, principally the Thomas and scuppernong varieties, are well adapted to growth in eastern Carolina, the fruit lending itself admirably to the production of home-made products such as grape juice, jellies, preserves, and other excellent foodstuffs.

To put these findings before the people of the State, there was held a short course, or grape products school, on this farm during the latter part of the year. Home Demonstration Agents from over the entire

southeast were present. Dr. George Dearing of the Bureau of Plant Industry had charge of the course of instruction, and explained carefully to the extension workers all the findings accumulated during the several years of investigational work. The idea of the Station is to gradually build up a great industry in home-made grape products. A number of women and girls in the home demonstration clubs have already taken up this project with good results.

The Division of Entomology determined, through research work in the field, that the soybean worm can be controlled in a practical way by dusting with dry arsenate of lead, mixed with dust lime in the proportion of 1 to 8. They found it was not necessary to attempt to get this poison on the under side of the leaves, as the worms quickly ate their way through and devoured enough of the poisonous material to cause their destruction.

In experiments with priming tobacco, as compared with cutting the stalk, the Division of Agronomy has determined in six years work, that considerable money can be saved tobacco growers by priming off the leaves as they mature. Fully 75 per cent of the tobacco growers of Granville County, in which the experiments were conducted, and from 40 to 75 per cent of the growers in the adjoining counties, have changed their methods of harvesting the tobacco crop since these results were published. The best tobacco men of the section estimated that this one thing has *saved farmers, during the past three years, not less than three to four million dollars, at the present prevailing prices.*

It has also been determined, in the work at this farm, that muriate of potash will make equally as good tobacco as will sulphate potash, from the standpoint of the grower. The Station is not ready, however, to advocate this practice generally, as no doubt the muriate form injures the burning quality of the tobacco produced.

In experiments recently concluded in some of the cheese factories of western North Carolina, it has been determined that from 8 to 9 pounds of cream can be secured from each 2,000 pounds of whey by the use of a whey separator. As this is a profitable investment for the factory, the machine costing only $400, one of the cheese factories has already purchased such a machine and installed it for permanent use. It is expected that the other factories will rapidly follow this example.

The Division of Animal Industry has found also that fish meal is a cheaper animal feed than tankage, causing slightly higher gains at a less cost. As fish meal is much more easily secured in North Carolina than the packing-house product, this work opens an important field for more economical feeding of hogs in the State.

It has also been determined from research work done with over a dozen dairy herds, that it cost just about 60 cents per gallon to produce and deliver milk. This is perhaps the most accurate information that has yet been secured on the cost of producing milk on the actual farm conditions in North Carolina.

One other notable piece of work to which attention should be called at this time is the result of the Division of Markets and the Animal Industry Division, in coöperation with the county agents of the Extension Service, to make coöperative shipments of livestock by the farmers. The investigations which have been done on this problem show that it is a very profitable thing for farmers to thus associate themselves and make such shipments. During the year many shipments of live hogs and sheep have been made to the larger markets. Several shipments of purebred cattle have been brought in in a similar way.

In the building of warehouses for cotton and other produce, reports during the year indicate that at least eleven counties of the State are making their plans to build, or have already begun construction under the State warehouse law, as administered by the Division of Markets.

AGRICULTURAL MEETINGS HELD AND ATTENDED

As in the past, all the members of the Station staff have devoted considerable time to attending meetings which were arranged, either by the experimental or extension service workers. This was especially true of the State Farmers' Convention at West Raleigh, the annual livestock meetings at Charlotte, and at other important meetings called by county agents and others all over the State. The Farmers' Convention this year was one of the most successful yet to be held from the standpoint of attendance and program. It was really one of the strongest meetings ever given for the advancement of agricultural interest in the State.

As usual, the Experiment Station has enjoyed the fullest coöperation from several of the State institutions, the daily, weekly, and agricultural press, business organizations, and other individuals and institutions working for the advancement of agriculture in North Carolina. Especially valuable has been the coöperation of the papers, the railroad workers, banks, chambers of commerce, and the counties of the State.

AGRONOMY

The main problems confronting the workers of the Division of Agronomy have to do with determining the plant food deficiencies of the soil, how to improve these so as to produce maximum crops, and building up to higher yielding strains the main staple crops which are grown in the State.

As the work of the Agronomy Division is founded largely on the findings of the soil survey, this basic work is being planned and pushed as rapidly as possible. Surveys were made during the year of Vance and Moore counties, and Durham and Guilford counties are now being mapped. After the soils of a given section have been mapped, experimental work can then be planned to show just what is needed in this type of soil to produce maximum crops.

One of the great problems with which the Division is confronted is to conserve the fertility of the soil, especially by the growth and handling of leguminous crops. Studies upon the amount of fertilizer to use on cotton have shown that at this time farmers are possibly not using the amount of fertilizer needed to give the largest net returns per acre. For instance, at the Iredell farm it was shown that the profit secured from using 200 pounds of fertilizer in 1917 amounted to about $40; while that secured from using 600 pounds amounted to about $82 per acre.

On account of the lack of potash in some of the fertilizer mixtures, especially with cotton on the sandier soils of the State, the reduction in the amount of potash has not only reduced the yield of cotton, but, in some cases, has lowered the resistance power of the plants to disease, and, in this way, greatly affected the yield. It has been found that nitrate of soda and sulphate of ammonia are the most efficient carriers of nitrogen in the promotion of crop yields.

A supply of lime is the first thing, after drainage, to assure a good crop yield on the muckland soils of the State. Generally, two tons of carbonate of lime per acre will give better paying results than one ton, or three tons.

From the experiments made with tobacco at the different farms, it seems that this time from 2 to 4 per cent of potash in the fertilizer mixture will be sufficient for the soils at the experimental farms near Reidsville. Muriate of potash in the mixture also gives good results from the standpoint of the grower, as has been previously stated.

Results with tobacco also show that by closer planting and better fertilization, the yield can be practically doubled, with the quality maintained to a high average.

The Agronomy Division has conducted crop improvement work with cotton in twenty-three communities of fourteen counties during the past year. In each case, except one, these communities have been led to adopt a better variety than those widely grown before the tests were made. Nine growers are now improving their seed cotton, as a result of this community testing, and it is estimated that they will have practically 5,000 bushels of improved seed for sale this fall. The Division is continuing its work of breeding high yielding strains of all the different leading crops of the State. The variety tests have proven that certain strains give larger yields in the different sections of the State. Experimental data are available now to show just which of these strains or varieties are more satisfactory. Some of the present high yielding varieties are also being bred up to a still higher standard, in order that the crop yields of the State may be constantly improved.

CHEMISTRY

The strictly research work of the Division of Chemistry has been continued along the same lines as in previous years, with the investi-

gators trying to determine at this time the best methods for use by mill operatives to produce a nontoxic cottonseed meal that will not injure the animals to which it is fed. Some investigations made during the year have determined why heating reduces the toxicity of cottonseed meal. The Division has shown that this toxicity is due to the presence of gossypol. This substance may be present in an unchanged form, or it may be changed to a nearly related substance which the Division has designated as D-gossypol, or it may be changed to some other substance. As a matter of fact, the gossypol itself seems to be more toxic than any of the substances derived from it.

ANIMAL INDUSTRY

As reported during previous years, the work of the Animal Industry Division is divided into various offices having charge of the classes of animals with which investigational work is being done. The work with swine is now being handled mainly on the Central Station Farm at Raleigh, and at two of the branch stations.

Some interesting experiments have recently been completed that show the importance of using a mineral mixture in the ration for hogs. It was found that where no mineral mixture was used it cost $24.96 to make 100 pounds of increase in live weight. Where a home-made mineral mixture was used it cost only $16.38 to make this 100 pounds increase. The one made and recommended, as a result of this experiment, consists of a mixture of 10 pounds of crushed charcoal, 5 pounds of air-slaked lime, 4 pounds of salt, 2 pounds of sulphur, and 2 pounds of copperas.

The work with swine has shown also that fish meal can be substituted for tankage, with the hogs making equally as good gains at a smaller cost. Some excellent data have also been secured on the curing of meat on the home farm. It has been found, during the past five years, that the shrinkage of cured meats, when liquid smoke was used, amounts to about 12.7 per cent, while the shrinkage when hickory smoke was used is 12.9 per cent. This proves, therefore, that the claims of the manufacturers of liquid smoke that their product permits the curing of meat with much less shrinkage is not justified. This work has also proven that meat cured from hogs fed on soybean pastures showed a shrinkage of 20.6 per cent, that meat from hogs fattened on peanut pastures gave a shrinkage during the curing process of 16.9 per cent, while the meat cured from hogs that had never been on a peanut or soybean pasture gave a shrinkage of 19.4 per cent. Some of the packers have discriminated against softbodied pork, giving as their reason that it showed a greater shrinkage on curing. This experiment, therefore shows that their claims are not justified.

Some excellent investigational work has been done during the year with poultry. Especially important has been that on the cost of raising chicks, which shows that at the present prevailing prices, the cost of the

feed for a chick is about 20 cents a pound, and this represents about 50 per cent of the cost of raising the chick during 1919.

In the breeding work with single combed white leghorns, the flock of birds layed an average of 89 eggs at the beginning of the experimental work. These have been bred and show an average of 135 eggs per year for the first two years since improvements have been made in the flock.

Dr. B. F. Kaupp is also making some interesting nutritional studies such as the mineral requirements for the growing birds, the value of velvet bean meal, and the use of skimmed milk in the ration for chicks.

Cottonseed meal is one of the standard feeds of the South, and is well suited to both sheep and beef cattle. Investigations are now being conducted to find out just how much of this meal may be used in the ration of breeding animals, and just how much roughage may be fed with it in a ration for sheep for best results.

Considerable work is also being continued on the wintering of stockers and feeder cattle in the mountains of western North Carolina, on the farm of Mr. T. L. Gwynn. These experiments have determined that it costs only half as much to keep the cattle through the winter on pasture as it does to winter them on such feeds as hay, corn silage, stover, straw, and grain.

Some of the outstanding efforts of the Dairy Office have been in a study of the cost of milk production, done in coöperation with the Federal Department of Agriculture. This work is now ready for publication, and a summary shows that it cost the farmers around Greensboro, where most of the studies were made, about 60 cents a gallon to produce and deliver their milk. This is perhaps the most accurate information that has yet been secured on producing milk under actual farm conditions.

The investigations made on recovering cream from whey at the Cove Creek Cheese Factory has resulted in this factory purchasing a whey separator, and it is probable that their action will be followed by other factories in this section.

As a whole, the Animal Industry Division has been unusually active during the year, as shown by the fact that they have held a total of 574 meetings, at which there were around 31,000 people. The members of this Division have also written about 22,000 letters in answer to requests for information. This is in addition to publishing articles in magazines, and in the newspapers of the State.

ENTOMOLOGY

Good progress has been made on all of the projects being studied by the Division of Entomology. The work with spraying potatoes has now completed its sixth year, with the past year showing a gain of 53 bushels of potatoes per acre by spraying with the home-made poisoned Bordeaux mixture. With early potatoes, increases varying from 50 to 191 per cent have been secured.

With the Larger Corn Stalk Borer, the experiments conducted over five years show that these borers may be greatly decreased by plowing under the stubble in winter, or by planting corn around May 25, as when planted at this date corn is only subject to the attack of one generation. When planted earlier, two generations affect the plants.

By dusting cabbage with arsenate of lead in air slaked lime it is found that an expenditure of around $6 will bring increased returns, varying from $50 to $175 in value, according to the prevailing market prices for the product.

The survey of the insect life of the State, which was begun 19 years ago, is being continued. During this year 147 species of insects have been added to the total list, which brings the number to 5,191 species at this time.

The work with the green clover worm on soybeans has been especially important during the year, due to the serious epidemic of this pest in the eastern part of the State. The studies made in the field, however, have shown that it may be controlled by poisoning with dry arsenate of lead, mixed with dust lime in the proportion of 1 to 8.

The Division has also traced the boll weevil into the State. This insect is now found in four of the extreme southeastern counties.

A great deal of work has also been done on a study of the leaf hoppers of the State, many field studies being conducted, as well as detailed work in the laboratory. The investigations on the control of the tobacco flea beetle have been completed and published in Bulletin No. 239. The experiments with the corn root worm are being continued at four different points in the State, and some valuable data have been secured with reference to this pest.

HORTICULTURE

In addition to the projects which have been studied during the past several years, a number of additional lines of work have been added during the year. The Division has now secured some additional workers for the purpose of carrying on these investigations. As heretofore, these investigations are concerned principally with pomology, a study of the native fruits, investigations with peaches, pecans, strawberries, vegetables, and with the muscadine type of grapes.

All the important varieties of fruit grown in the State are being studied to show the range of adaptability of the varieties in the different sections. The native fruits of North Carolina, their place of origin, their history and description are also being thoroughly studied, with paintings and photographs made of the most important varieties found.

In dehorning peach trees, it has been found that when buds are winter-killed by cold, this dehorning can be profitably done to renew the old trees. A good deal of interesting work is also under way to improve the present commercial varieties of peaches. A variety orchard containing about 60 different varieties of peaches was planted during 1917,

and these trees have now grown so satisfactorily that much active work can be done.

Twenty-two varieties of pecans have now been studied for nearly thirteen years, giving the Division of Horticulture enough accurate data to make recommendations regarding the best varieties for use in this State. During the past year the trees produced the largest crop of nuts in their history, some of them yielding over 50 pounds. Much information has been secured as to the best cultural practices of pecans, and methods of breeding and top working.

In the investigations with strawberries, twenty-three varieties have been tested in comparison with the Klondike and Missionary. While none of these varieties have shown themselves superior to these two for commercial purposes, a number of them have proven themselves valuable for home use.

About 19 varieties of sweet potatoes are being studied in eastern North Carolina to determine those most desirable from the standpoint of productivity, market value, and keeping quality. These tests are being made to determine the behavior of the different varieties in storage. It has been found that when good houses are used, the average loss from all varieties has been less than six per cent during the past year.

About twenty varieties of Irish potatoes are being studied to determine those best suited to conditions in western North Carolina.

At the Trucking Branch Station, in Pender County, the Division has a year-round observation garden that has been of much value as a demonstration in proving to the people of eastern North Carolina that a year-round garden is possible.

In connection with the investigations with the muscadine type of grape, six important lines of work are being attempted. Some of this work has already been reported on in the technical publications of the Station, notably Technical Bulletins Nos. 12, 17, and 18.

PLANT PATHOLOGY AND BACTERIOLOGY

Due to the resignation of Dr. W. H. Tisdale, who was in charge of the plant disease work during the absence of Dr. F. A. Wolf, in army service, the work in this Division has been hindered during the year. However, much data of value have been secured, especially in the laboratory. It is now planned to extend this work to field conditions for the purpose of securing adequate proof on methods of control of the several diseases which have been studied.

The Division has devoted considerable time to a heretofore little known vetch disease. It was very destructive in North Carolina during 1919, in a number of cases preventing the formation of seed.

The Division has issued one publication during the year, this being on Clover Stem Rot. Methods of control of the clover stem rot have been worked out, but in badly affected fields it has been found that cowpeas and soybeans must replace crimson clover as a legume in the rotation,

and winter grains must serve as cover crops if the disease is to be eliminated in any particular field.

One of the interesting lines of work in which the Division has been engaged during the year has been a study of the diseases of flue-cured tobacco, in coöperation with Mr. E. G. Moss of the Tobacco Experiment Station. Considerable data have been accumulated on this subject, and have been prepared in manuscript form for publication.

MARKETS AND RURAL ORGANIZATIONS

As heretofore, the work of this Division has to do with problems of marketing, warehousing, rural credits, and the proper grading of agricultural products. The Division has been especially active during the year in making surveys, in organizing the State cotton warehouse system, and in assisting in the formation of marketing exchanges. A number of surveys have been made which show the need of cotton warehousing and better credit facilities. While there are a great many small warehouses, these surveys show that there is still need for a much greater number.

The advantages of a warehouse can be seen in the fact that one warehouse holding 5,000 bales, which cost $15,000 to construct, made $125,000 for those who stored cotton in it that year. One bank loaned $250,000 on the cotton which it contained. The surveys show also that the large farmer usually obtains a higher price for his cotton, and if farmers were so organized to market their staple in large, even running lots through their own warehouse companies, they would not now be selling it at from one to four cents below the market, and losing in most places from $5 to $20 per bale.

With grain and soybeans there is also a great lack of warehouse space. The demand for corn has been less, due to the lack of a demand for wheat flour substitutes. Corn has been sold at a lower price than before, and soybeans sold from $1.50 to $2 per bushel, as compared to $3 and $4 last year. However, when the farmers had sold practically all of their beans, the price immediately rose to $3 per bushel, or better. The same is true of peanuts, in that immediately after the armistice there was a great decline from 9 cents a pound to about 4 cents. Reassurance to the growers on the part of the Division aided them in holding their nuts until the price had again reached a better figure.

Little selling assistance has been necessary in sweet potatoes, as the prices have generally been good. With the mountain products it was found that the growers had best have their Irish potatoes for sale in the late summer or early fall, as this is the only time that it pays them to put this crop on the market.

With hog marketing, the Division assisted in making eighteen coöperative shipments of fat hogs during the year. This idea is rapidly spreading over the entire State, and has been found to be a very profitable

method of marketing on the part of those farmers who have only a small number for sale.

Surveys with beef cattle indicate that the prices obtained by growers are usually considerably below the actual value of the cattle, due to the improper marketing conditions. Some sell their cattle too early, while others sell to dealers who contract with them anywhere from one to six months before delivery. Coöperative selling of fat cattle direct to the packers is being advocated to remedy this evil. The Division is planning to hold two big sales during the next year, and to develop the coöperative marketing scheme.

With sheep and wool, there were six coöperative shipments of sheep, while the wool from eight counties was collected and shipped to Philadelphia under the supervision of a livestock specialist. This idea is being pushed. It is planned to assemble all of the wool of the State in three or four places, and then offer it at auction.

The Division has devoted considerable time and attention to the organization of the State cotton warehouse system during the past year. Plans for handling this work have about been worked out, and at least eleven counties have taken up the proposition of building houses to store cotton when the price is too low. Surveys showed that cotton is damaged at least $2.50 per bale when allowed to lie in the open, and that this amount would supply enough money, if saved, to build all the warehouses needed in the State.

In the promotion and maintenance of marketing associations, the Division has aided in establishing one cold storage and marketing association for handling apples, potatoes, and cabbage in the mountains, two potato and cotton warehouses, and one strawberry association in eastern North Carolina.

At Aurora the Eastern Carolina Produce Exchange has been promoted for marketing Irish potatoes, with 150 cars being shipped during June, saving the growers from $15,000 to $25,000.

The Carolina Potato Exchange at Elizabeth City marketed for its members last year 169 cars of Irish and sweet potatoes at a good profit.

The Tabor Produce Exchange marketed 25 cars of strawberries, and the Mountain Growers' Exchange at Waynesville looked after the marketing of the perishable products grown in the mountains. Six carloads of late Irish potatoes were handled through this organization.

Twelve new credit unions were organized during the year, and three old ones given a new start. The resources of these unions have doubled during the past year.

Another matter to which the Division is rendering very valuable assistance is in the classing of cotton for farmers of the State. Six grading offices were maintained during the past year, and 26,081 bales of cotton were classed for farmers, and 4,036 were classed for cotton mills.

The Division also gave general assistance in the marketing of all products to individuals by listing these in a monthly farmers' market bulletin, and by personal assistance in finding markets where none existed locally.

DRAINAGE

The investigations of the Division of Drainage have been concerned chiefly with the question of farm drainage, making preliminary examinations of drainage districts, studying run-off on drainage canals, the efficiency of under-drains, and maintenance work on drainage canals.

During the past year preliminary examinations, surveys, designs, and reports for tile drainage systems have been made on 24 farms, in eleven counties, comprising a total area of 1,200 acres. Approximately 12,000 feet of tile have been installed on these farms.

Members of the Division have also given assistance on 36 farms in 19 counties to locate and construct terraces for the prevention of erosion. Approximately 44 miles of terracing have been laid out. Six examinations for drainage have been made, and reports issued to cover a total area of 119,000 acres. On Third Creek, in Iredell County, gaging stations for the determination of run-off have been studied on a watershed area of 44,000 acres.

The efficiency of under-drains has also been studied on two systems in Edgecombe County. This work has been in progress since 1916, and much valuable data is being secured.

For the purpose of studying the best methods and the cost of maintenance of drainage canals in North Carolina, about two miles of dredged canal, through Jacob Swamp in Robeson County, are being studied by the Division. A summarized report of this work for the years 1917 and 1918 has been prepared.

PUBLICATIONS

In addition to an Annual Report of 1,000 copies, four publications have been issued during the year. Bulletin No. 239, "The Tobacco Flea Beetle," and Bulletin No. 241, "Soybeans and Cowpeas for North Carolina," were printed, with a total issue of 26,000. Two technical bulletins, No. 15, "A Monograph on Trembles or Milk Sickness and White Snakeroot," and No. 16, "Clover Stem Rot," were also issued.

The experimental work, as heretofore, has been kept constantly before the people by means of articles in the Extension Farm News, and in the Special News Service supplied to the press of the State.

The bulletins of the Department of Agriculture have also been used to give the results of the experimental findings of the Station workers. These have been issued, one each month, with about 15,000 copies of each bulletin being printed.

Multigraph material has been edited and distributed to the special mailing lists maintained by the Station. There is now a total of around 60,000 names on the various mailing lists. These are kept up to date, and an effort has been made during the year to keep the lists from growing too large. However, all published material is well advertised in the press, and those who care to do so may secure copies by writing to the Station. In this way the publications are sent only to those who will be interested in receiving them.

Attention is called to the reports of the heads of the several divisions, and to the financial statements which follow:

FINANCIAL REPORT

The North Carolina Agricultural Experiment Station, in account with the United States Appropriation, 1918-1919:

Dr.

	Hatch Fund	*Adams Fund*
To receipts from the Treasurer of the United States, as per appropriations for the fiscal year ended June 30, 1919, under acts of Congress approved March 2, 1887 (Hatch Fund), and March 16, 1906 (Adams Fund)	$15,000.00	$15,000.00

Cr.

Salaries	$6,735.56	$12,659.07
Labor	2,888.79	896.15
Publications	895.97	
Postage and stationery	136.91	93.85
Freight and express	48.99	7.13
Heat, light, water, and power	168.45	84.25
Chemicals and laboratory supplies	54.77	127.87
Seeds, plants, and sundry supplies	689.01	204.22
Fertilizers	731.70	279.25
Feeding stuffs	1,097.36	9.00
Tools, machinery, and appliances	371.75	115.50
Scientific apparatus and specimens	115.00	107.04
Livestock	129.00	250.00
Traveling expenses	166.74	166.67
Contingent expenses	20.00	
Buildings and land	750.00	
Total	$15,000.00	$15,000.00

The North Carolina Agricultural Experiment Station, in account with Farm and Miscellaneous Receipts.

Dr.

Receipts from other sources than the United States for the year ending June 30, 1919	$7,370.83
Balance on hand	1,616.70
Total	$8,987.53

SUPPLEMENTAL STATEMENT

Cr.

Labor	$252.22
Postage and stationery	94.34
Freight and express	122.55
Heat, light, water, and power	11.39
Seeds, plants, and sundry supplies	17.96
Feeding stuffs	25.00
Library	534.53
Tools, machinery, and appliances	127.83
Furniture and fixtures	56.10
Livestock	810.00
Traveling expenses	25.73
Buildings and land	2,835.39
Balance	4,074.49
Total	$8,987.53

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the North Carolina Experiment Station for the fiscal year ending June 30, 1919; that we have found the same well kept and classified as above, and that the receipts for the year from the Treasury of the United States are shown to have been $30,000, and the corresponding disbursements $30,000, for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving nothing.

And we further certify that the expenditures have been solely for the purposes set forth in the acts of Congress, approved March 2, 1887, and March 16, 1906.

(Signed) C. E. Thompson,
D. R. Noland,
H. L. Stevens,
Auditors.

(Seal.)

Attest: A. F. Bowen, *Custodian.*

REPORT OF THE DIVISION OF AGRONOMY

To the Director:

During the year the main efforts of the workers of the Division of Agronomy have been (1) to determine the main plant food deficiencies of the soils of the State and how to most economically meet these in the profitable production of crops; (2) and in improvement work with the main crops of the State to secure more prolific strains of these through breeding.

Although the work has had many interruptions, the experiments have not only been kept in force and in good shape, but some progress has been made. Below is given a brief statement with reference to the status and progress of the main lines of work.

SOIL SURVEY

This work was interfered with by the war, more than any other line of work being carried on by the Division, because of the loss of all the men into military service. They have all now returned and work is progressing actively. During the year surveys of Vance and Moore counties have been completed, and work is now progressing in Durham and Guilford counties. At the present time there are three State and three Federal men in the field in the survey work. It is of the highest importance that the survey be pushed aggressively, so that the State may be completed at as early a date as possible.

As stated in previous reports, the soil survey is the basic work on which our field experiments are planned and are to proceed in the future.

CONSERVING FERTILITY OF THE SOIL

Of all times, this is the one that farmers of the State can least afford to neglect the producing powers of their soils. Where fertilizers are used intelligently, with most crops, they will pay as well or better now than they did three or four years ago, notwithstanding the material

advance in price. The reason for this is that farm products have advanced, in many cases, more than have the fertilizing materials.

Of all times, too, this is the one, as fertilizers are high, in which farmers should exercise the greatest care in the selection of the fertilizers to be used on their different crops. Growers should know the needs of their soils and of the crops that are to be grown, and buy most economically to meet these needs. The Division of Agronomy has a great amount of information with reference to the needs of different crops grown on different kinds of soils of the State, and is thus, at all times, prepared to supply this information to those seeking it.

Notwithstanding the high price of seed of most legumes, it is very essential, as far as it is practical, for farmers to utilize these to a greater extent than has been the case heretofore. Such crops, when handled properly, will supply nitrogen to the soil, the most expensive plant-food constituent needed by our soils. This constituent is one of the main limiting factors in the production of crops on most of our soils. In growing such crops as crimson clover, hairy vetch, red clover, bur clover, soybeans, cowpeas, and velvet beans, in the different localities where they are adapted, when these crops are put in well and inoculated properly, where need be, one is able to have a large amount of nitrogen taken from the illimitable supply of the air and stored in the soil when all or a part of these crops are plowed under. As far as practical for the farmer to do so, he should plow in some or most of these crops when grown on his farm. Especially is this so where they have been grown on soils that are low in organic matter. A moderate growth of each of these legumes on a field should, when turned under, add to the soil, of nitrogen taken from the air, something like 70 to 100 pounds per acre. Of course, the number of pounds added will depend upon the amount of growth, and to a less extent upon the kind of legume. If one will calculate what 75 pounds of nitrogen would cost now in commercial fertilizers, he will appreciate the value of a good growth on the soil of any of these leguminous crops.

In order to succeed on most of our soils, especially on those that have not received an application of lime during the past three or four years, it will ordinarily be necessary to make an application of ground limestone, or some other suitable form of lime, at the rate of a ton and a half to two tons of calcium carbonate per acre. Again, phosphoric acid will usually be required for best paying results. Generally, an application of 200 to 300 pounds per acre of 16 per cent acid phosphate will be sufficient on the better grade of soils. Where the soil is very poor, and no manure or leguminous crop has been plowed in the land, a small amount of cottonseed meal, or some other suitable carrier of nitrogen, should be used with the acid phosphate in suitable amounts to carry one to two per cent of nitrogen in the mixture.

Plants are the only things that can take materials from the soil and air and manufacture them into food products of different kinds for man

and beast. Therefore, it is of the highest importance that we treat our soils and handle our crops in the most favorable way, so that we may have them produce the largest possible amount of food. This will not only be a wise thing to do on the part of the State, but should at the same time be a profitable operation for the individual farmer.

EFFECT UPON PROFIT OF QUANTITY OF FERTILIZER USED ON COTTON

Attention is called to the fact that it has been found that the profitableness of the use of commercial fertilizers, not only depends upon the composition of the fertilizer used, but also upon the relative cost of the commercial fertilizer and the selling price of crop or crops. This fact is brought out very strikingly in the tables given below.

Where good farming is done, and the right kinds of fertilizers are used, generally, the quantity of fertilizer per acre is not in sufficient amounts to give the largest net returns. Other things being equal, the most profitable yields should be secured by materially increasing the yield per acre, above what they are on an average at present, and, if necessary to maintain a definite yield for the farm, reduce the acreage of the crop. In other words, where good farming is done, relatively large yields per acre are best. Not the largest yields, however, are always the most profitable ones. The above claims are based upon the results from long continued experiments conducted in different parts of the State.

Average Results at the Central Farm. Below is given the profit from the use of different quantities of fertilizer per acre in 1913 and in 1919:

Amount of Complete Fertilizer Per Acre— Pounds	*Value of Increase Per Acre Above Cost of Fertilizer*	
	In 1913	*In 1919*
200	$16.12	$37.97
400	19.57	46.11
600	25.50	50.06
800	22.01	51.85
1,200	22.04	51.95

In making the above calculations for profit in 1913 and 1919, the increased yields from the different fertilizer applications were used, above what was secured where no fertilizer was applied. The same average yields were used in making the calculations for 1913 as for 1919. The difference in the profitableness of the two years is due to the relatively higher selling price of the cotton, over the cost of fertilizers.

Average Results at Iredell Farm. Similar results for cotton, to those secured at the Central Farm, are given from data secured in many years study at the Iredell Farm. On this latter farm the quantity of complete fertilizer used per acre varied from 200 to 1,000 pounds applied in the drill at planting. Below is given the value of the increases in 1914 and in 1917, calculating at the average selling price of seed cotton and the cost price of commercial fertilizers prevailing during the two years.

The average results secured show the relative profitableness of different quantities of fertilizer used per acre in 1914 and in 1917 to be as follows:

Amount of Complete Fertilizer Per Acre— Pounds	*Value of Increase Per Acre Above Cost of Fertilizer*	
	In 1914	*In 1917*
200	$16.00	$40.13
400	27.59	69.59
600	32.30	82.11
800	33.84	86.16
1,000	36.86	95.38

Average Results at Edgecombe Farm. On this farm, which is located on the Norfolk fine sandy loam soil, the prevailing type in the eastern portion of the State, there have been, on an average, material increases in gains from the use of different quantities of a complete fertilizer up to 1,200 pounds per acre. The average results secured are as follows for 1914 and 1917:

Amount of Complete Fertilizer Per Acre— Pounds	*Value of Increase Per Acre Above Cost of Fertilizer*	
	In 1914	*In 1917*
300	$18.15	$45.34
600	24.40	62.13
900	27.90	72.31
1,200	34.55	90.06
1,500	33.50	89.32

It will be observed from the above data that on an average, both in 1914 and in 1917, the best paying results, above the cost of fertilizer, were from an application of 1,200 pounds per acre. When the quantity was increased above this the profit was less.

POTASH REQUIREMENTS OF EASTERN NORTH CAROLINA SOILS

If satisfactory crops are to be produced, it has been found absolutely necessary, in addition to supplying a sufficiency of available phosphoric acid and nitrogen to the soil, that ample potash, too, will be present in suitable form to supply the needs of the growing crop. Where too small an amount of this constituent in available form is present in the soil for good yields, the crop cannot be other than small.

Before the breaking out of the European War, the farmers in this State, as well as those throughout the country, were almost entirely dependent upon the deposits in Germany for their supply of potash contained in the fertilizer mixtures they were using. Hence, when this great catastrophe came, and all shipments from Germany were cut off, it left this country almost entirely, for the time being, without a potash supply suitable for agricultural purposes, except a small reserve which was in the hands of dealers, manufacturers and farmers, and that derived from waste products on farms. In consequence of this condition, the price of potash shot upward and has ever since remained high in price, notwithstanding the fact that a considerable domestic supply of this constituent has been developed during the past three or four years.

As a consequence of the scarcity and high price of potash, there has been, on the part of farmers of this State, a material reduction in the percentage of this constituent used in the fertilizer mixtures for different crops, and in many cases the reduction has been to such an extent as to materially affect the yields, as well as the quality of the crops. Particularly has this been the case with such crops as tobacco, which require a large amount of potash to produce the highest grades. In the growth of cotton on some of the sandier soils of the eastern part of the State, the leaving out, or the reduction of potash in the fertilizer mixtures to too small a percentage has, in many cases, not only directly affected the yields, but appears to have materially lowered these by reducing the resistance power of the plants to some of the more common diseases to which cotton is sometimes subject, when grown on some soils in this State. Crops are dependent upon the potash present in the soil, or that added in available forms in fertilizing materials. It is, therefore, of the highest importance that a sufficiency of this constituent be present in the soil in available form, so that plants can make satisfactory growth; in other words, so that potash will not be the limiting factor in the growth of crops.

Outside of the Albemarle section of the State, most of the soils thus far studied in the east contain from a moderate to a low content of potash. Even with the soils in the Albemarle section that are high in potash, it has frequently been found advisable to add this constituent to some crops in order to get the best paying results. Especially has this been found true of crops like tobacco and potatoes that require considerable amounts of potash when grown on soils low in organic matter. It should not be inferred from this, however, that a lavish use of materials carrying potash is to be recommended. As a matter of fact, it is of the highest importance that only amounts needed by the crops shall be added to supplement that which is available in the soil. The potash in eastern soils, generally, appears to be contained in rather a refractory form, so that it is brought into solution in the soil water only with the greatest difficulty. Generally speaking, however, this constituent frequently comes next to nitrogen in importance, and must be supplied to the soils for the best growth of the main crops grown in that section of the State.

There are sources of this constituent in the waste materials on every farm, that have not heretofore been carefully saved and applied to the soil, because of the fact that farmers felt that potash could, in many cases, be bought more cheaply than when derived from waste materials around the farm. Wood ashes, when properly looked after, will supply a good amount of this constituent. However, if they have been allowed to lie out in the rain the potash which they contain, being readily soluble, would be washed away. A good grade of wood ashes that has not been allowed to leach will ordinarily contain from 4 to 6 per cent of potash. If leached thoroughly, the percentage of potash would probably be reduced to from ½ to 2 per cent, the amount left in the ashes being de-

pendent upon the amount of leaching. It is, therefore, of the highest importance that ashes, where wood is burned on the farm, should be saved to be applied to the field crops that have the greatest need for this constituent. The ashes derived from hardwoods will ordinarily contain a higher percentage of potash than will those that come from the soft woods, like pine. Coal ashes have practically no fertilizing value and, therefore, should not be saved to apply to the soil with the hope of supplying potash. Woods mould, stable manure, and other farm manures of different kinds contain more or less potash, although their main constituent is generally nitrogen. These materials should be carefully saved to apply to the soil, as they supply potash, as well as nitrogen and phosphoric acid. One of the most important sources of potash on tobacco farms is tobacco stems and waste tobacco leaves. At the present price, tobacco stems and leaves per ton will contain from $25 to $35 worth of this constituent. In other words, it would require the expenditure of this amount in commercial fertilizer to purchase the same amount that is contained in these waste materials on many tobacco farms. All these materials should be scrupulously saved and applied to the fields, as they will supply the required amount of potash needed by the plants for the following year. In order to facilitate their rotting, they can either be chopped up or composted.

RELATIVE EFFICIENCY OF DIFFERENT CARRIERS OF NITROGENOUS MATERIALS

The relative value of nitrate of soda, sulphate of ammonia, calcium cyanamid, dried blood, and cottonseed meal, as carriers of nitrogen in commercial fertilizers, has been brought out as the results of long continued field experiments by the Division of Agronomy.

The experiments were conducted on the large soil type areas of North Carolina to determine the relative efficiency of the different carriers of nitrogen for plant food purposes, as measured by crop yields. From the results of work that has been conducted up to this year, it has been found that nitrate of soda and sulphate of ammonia are most efficient in promoting crop yields.

Particular attention is called to the fact that there are conditions under which these materials cannot be used very satisfactorily, except in a rather prescribed way. For instance, on very coarse sandy soils, that are underlain by a coarse sandy subsoil, and, therefore, of a very leachy nature, these very soluble materials are likely to be lost from such soils before crops are able to secure much of them, if applied at the time the crop is planted. Especially will this be so if the season is at all wet; under which circumstances they have to be used with considerable precaution. These precautions were, of course, observed when measuring the efficiency of these carriers as against the organic carriers—cottonseed meal, dried blood, and calcium cyanamid.

The average field results show that the efficiency of the different common nitrogenous fertilizer carriers is nitrate of soda, sulphate of ammonia, calcium cyanamid, dried blood, and cottonseed meal for cotton —and nitrate of soda, sulphate of ammonia, calcium cyanamid, cottonseed meal, and dried blood for corn in the order given when the yields were considered. The same amount of nitrogen for the same crops was equal from all sources each year. There was a normal application of phosphoric acid and potash used with the different nitrogenous carriers.

SOIL FERTILITY INVESTIGATIONS

The main work in soil fertility is being conducted by the Division of Agronomy at the Buncombe, Iredell, Central, Granville, Edgecombe, Washington, and Pender farms. Throughout the State many soil type experiments are being conducted on the farms of farmers for the purpose of supplementing the main lines of investigation. These latter are so located that the results from them will have as wide application as possible to the main soil type areas found in the State. It has been found in these experiments that not only the farmer carrying on the coöperative work is much interested in the results of the experiments, and has used them to benefit himself, but other farms in the respective communities are beginning to use the results in their farming operations. At present, the outlying fields are located on the types of soil and at the points given below:

For Mountain Section

On Toxaway Silty Loam, near Andrews.

For Piedmont Section

On Cecil Sandy Loam, near Winston.
On Cecil Sandy Loam, near Gastonia.
On Mecklenburg Clay Loam, near Concord.
On Granville Sandy Loam, near Franklinton.
On Granville Coarse Sandy Loam, near Louisburg.

For Coastal Plain Section

On Norfolk Fine Sandy Loam, near Rocky Mount.
On Portsmouth Fine Sandy Loam, near Pantego.
On Muck, near Moyock.

The Division is also carrying on similar soil fertility work, in cooperation with a number of farm life schools of the State, with the idea that the results will be of considerable value to the teachers of agriculture in these schools in vitalizing the subject of agriculture with their students. It is felt, too, that the results of these experiments should be of considerable value to the farmers in the communities surrounding these schools, and should be a means of drawing the attention of the patrons to the value of the work which is being done on the school farms,

and also to the reliability of the information which the teachers of the different schools are giving to the boys studying agriculture. These latter tests are being carried on at the following points:

In Piedmont Section

China Grove Farm Life School, in Cabarrus County.
Lowe's Grove Farm Life School, in Durham County.
Parrish Agricultural High School, in Durham County.
Jamestown High School, in Guilford County.

In Coastal Plain Section

Red Oak Farm Life School, in Nash County.
Philadelphus Farm Life School, in Robeson County.
Sand Hill Farm Life School, in Moore County.
Craven Farm Life School, in Craven County.
Aulander Farm Life School, in Bertie County.
Wakelon Farm Life School, in Wake County.

SPECIAL TESTS

These tests were started during the past spring at Whitakers and Williamston to study the effects of lime, gypsum, and sulphur upon the yield and growth of peanuts. It is too early yet to make any deductions from results secured.

At Aberdeen, Lowe's Grove, and at the Central Farm tests were started this spring, too, to determine the value of nitrate of soda and sulphate of ammonia as a top dressing for cotton. In these tests, applications of the nitrogenous materials were made to the crop on four different dates during the growing season.

At the Washington Farm. In fertilizer experiments at this farm it has been planned to study the effect of different combinations of fertilizers on the peat soils, with and without lime when used singly, in combination with two, and with all three of the plant food constituents. In the test, one plat has been supplied with basic slag, as a source of phosphoric acid, for a comparison with acid phosphate as a carrier of this constituent. Although there have been some crop failures in these experiments, sufficient data is available at present to cause us to believe that a supply of lime is the first thing required after drainage, to be assured of good crop yields. The use of two tons of carbonate of lime per acre has given better paying results than has the use of one ton. Three tons per acre have been found less effective than the use of two tons. Burnt lime, up to this time, has not been found superior to raw ground limestone as a carrier of lime in the carbonate form. The addition of phosphoric acid and potash, used alone and in combination, has shown no benefit, and sometimes has had a depressing effect upon the yields.

In the growth of corn, oats, and soybeans on Field A, corn thus far has been the only successful crop. It is possible that oats might have done better. Soybeans grown under the conditions existing here, it is felt, should, by all means, be inoculated. Nitrogen, in one case, has shown some benefit, but on an average, when used alone and with phosphoric acid and potash, has been found to have but little value for the soils of this farm in their present condition.

Increasing the amount of lime per acre to about two tons has resulted in increased crop yields. To be enabled to answer the question as to how much and what form or forms of lime to use on the kind of soil, as represented by this farm, special lime experiments were begun during the spring of 1917; three forms of lime—hydrated, ground limestone, and marl—being tested. The quantities of each that are being used in the experiment have been secured, and indications are that the use of more than one ton of lime per acre is needed for best crop returns. There is a strong indication, too, from the data thus far secured, that marl is not as efficient a carrier of calcium carbonate as the other forms of lime. The need of lime was strikingly shown during the past winter and spring with a cover crop of rye on the regular fertilizer plats. Up to the first of February of this year, over the entire field, both where lime was applied and where it was not, there was a good stand of rye. Soon after this date, the crop on the unlimed end of the plats began to die out, until by the first of April the land was practically bare. The growth of rye on all the plats where lime was used produced a very good growth.

At the Pender Farm. Experiments are being conducted at this farm to determine the combination of plant food constituents best suited for the growth of corn, oats and vetch, and cotton in a three-year rotation. Because of severe attacks of corn bill bug, and other unfavorable conditions, there have been some failures in the crops. So far, nitrogen has been proven the best constituent for better crops. Phosphoric acid with nitrogen has given more increase than has potash with nitrogen.

The use of lime has shown up well, especially with soybeans. In the experiments, basic slag up to this time has not been found quite as satisfactory a carrier of phosphoric acid as has acid phosphate.

Last year an experiment was started to test the relative efficiency of the different common carriers of phosphoric acid, with and without applications of lime.

At the Edgecombe Farm. The main fertilizer tests at this farm are conducted on Fields A, B, and C. On these fields a three-year rotation of corn, cotton, and peanuts, with a cover crop each year, is being used. From the average of these tests, nitrogen and potash have shown to be constituents of plant-food of first importance for best crop yields. When larger amounts of nitrogen and potash are used in the experiments, phosphoric acid begins to show up to much greater advantage. The results, as a whole, show in a very striking way that farmers, generally, in the eastern section of the State, are not using enough fertilizer for cotton

to secure the best paying returns per acre, as long as cotton remains high in price. Neither is the fertilizer best proportioned ordinarily for the most economical gains. Ordinarily, more nitrogen and potash should be used in the mixtures, and a little less phosphoric acid. The use of lime alone has shown splendid returns for each dollar invested on both cotton and corn.

In the rotation tests, the results show that corn and cotton, on the same land every year, afford better yields than a rotation of corn and cotton when fertilizer is used in all cases. When legumes are used in the rotation, and a crop of oats is included, much better yields of all crops are produced. The study of the value of farm manure has led to the belief that the organic matter which it contains is an important factor on the character of soil found at this farm.

In the study of different sources of nitrogen, nitrate of soda still leads as a carrier of nitrogen in crop production, with sulphate of ammonia coming second.

A test has been started on this farm recently to determine the relative winter-killing of crimson clover grown from foreign and native seed.

At the Iredell Farm. On the cecil sandy loam soil of this farm, the evidence is still conclusive that the use of available forms of phosphoric acid and nitrogen are the main controlling factors in the hands of the farmer for the production of better crop yields. With both cotton and corn, on an average, the use of lime has given splendid results. It is believed that, as the organic matter supply of these soils is increased, it will have a marked effect upon the beneficial influence of lime applications and commercial fertilizers, as measured by crop yields.

In the rotation tests, the average results show that corn every year and wheat every year with fertilizers are no more exhausting upon the fertility of the soil than a two-year rotation of corn and wheat with fertilizers. By the use of legumes, like red clover in the rotation, a marked increase in the yields of both crops is secured.

In the study of the different carriers of nitrogen, nitrate of soda, and sulphate of ammonia, the mineral sources have been shown to be more efficient in the promotion of crop growth and yields than the organic sources like dried blood and cottonseed meal. There appears to be no residual nitrogen left in the soil, as indicated by crop growth on those plats which have received organic carriers of nitrogen. Potash used alone has been frequently observed to depress the yields below what was secured where no fertilizer at all was applied on this farm.

In the spring of 1919, a test was started to show the value of soft phosphate rock, as compared with acid phosphate in supplying phosphoric acid to crops. From the first two pickings of cotton on this field this fall, acid phosphate appears to be giving better returns.

The experiments at this farm have brought out very strikingly the poor results secured in the growth of red clover without the use of lime. By supplying lime fairly liberally, and using a small amount of ferti-

lizer, it has been found, ordinarily, that one can be assured of a successful growth of clover; provided the seed are put in properly.

At the Buncombe Farm. In the regular fertilizer experiments on this farm, phosphoric acid, nitrogen, and lime seem to be the controlling constituents for the production of better crop yields, on both the bottom and upland soils.

With the rock phosphate tests, in which a comparison is being made of the value of this material, with acid phosphate as a source of phosphoric acid in crop growth, where both materials have been used, with stable manure and with legumes, the acid phosphate has given greater and more profitable yields under all conditions and with all crops, than has rock phosphate.

For the first few years at this farm the use of lime did not show up to be very beneficial. However, during the past two or three years the results are much more striking in showing the value of this material. Results show this material much more beneficial and essential for red clover and corn than for wheat.

At the Central Farm. Here the experiments have brought out very strikingly the importance of having more vegetable matter incorporated in the soil, so that crops will be enabled to take better advantage of the fertilizers which are applied. Nitrogen and phosphoric acid have given materially increased yields. The use of potash, in combination with these constituents, has been shown to be of little importance, as long as potash remains as high in price as it is at the present time. Certainly not until after nitrogen has been added in goodly amounts. It has been shown that a rotation simply of corn and cotton, without the use of lime, and using rye and crimson clover as winter cover crops, will not do very much alone for the improvement of the character of soils, as represented by those found at this farm.

A test was started this year to determine the relative efficiency of nitrate of soda and sulphate of ammonia as carriers of nitrogen for cotton, when applied on four different dates during the growing season. This test is planned to be conducted for several years before attempting to make any conclusions.

Experiments have been started, too, to study the value of phosphogerm and Trona potash as fertilizing materials.

Tobacco Experiments at the Reidsville Farm. The experiments with tobacco, to determine the best and most profitable combinations of fertilizer to use per acre, have been continued. From the results of the fertilizer experiment, the use of 800 to 1,000 pounds per acre of fertilizer containing about 8 per cent available phosphoric acid, and about 4 per cent ammonia, and 3 per cent potash is to be recommended for tobacco grown on the lighter soils. On those soils of the stiffer mulatto type, 600 to 800 pounds of an 8-3-3 fertilizer have been found to give good results.

At this farm a special series of potash plats is being conducted to determine the need of potash in tobacco growing. The results of this test bear out the evidence that previous year's work, with even quite small applications of potash, have a very favorable influence and profitable effect upon both the yield and quality of tobacco. It seems probable, from the data thus far secured, that, ordinarily, 2 to 4 per cent of potash in the fertilizer mixture will be sufficient.

The tobacco on the muriate plats during the year has looked slightly better than that which received sulphate of potash. The former seemed, too, to have been affected less by "sand-drown." A new feature of the work this year was the putting out of a special set of nitrogen plats, in duplicate, to test the comparative value of different sources of fertilization of tobacco. It is interesting to note that nitrate of ammonia (a product from the Muscle Shoals Nitrate Plant of the Federal Government) has given excellent results with tobacco. In the field tests the increased yields produced by lime have been noted. The tobacco, however, is somewhat coarser and darker where lime was used.

Here, as at the Granville Farm, a test is being carried on to determine the relative value of harvesting tobacco by priming and by cutting. In the rotation work with tobacco it is especially interesting to note the marked favorable effect of grasses.

A test has been made at this farm on the value of basic ferric sulphate for which considerable claims have been made as to its value. The result of one year's test does not indicate that it is valuable for the growth of tobacco.

In the study of crop relations or the inter-relations between fertilizers and crops, as they affect the crop producing power of the soil, it has been found that the cultivation of tobacco, as commonly grown and fertilized on land is not as exhaustive as is a crop of corn, ordinarily handled.

TOBACCO WORK AT GRANVILLE FARM

General Fertilizer Tests. In these tests there are thirty-six plats. Tests are being made of different sources of nitrogen, phosphoric acid, and potash for tobacco. These plats have now been going for nine years, this year completing the third cycle of rotations. The results have been very interesting, showing marked differences between the organic and inorganic nitrogen, also between the different combinations of these. Acid phosphate seems to be the best source for phosphoric acid applied under flue-cured tobacco, as the bone meal and basic slag do not mature the tobacco rapidly enough. Under present market conditions there is some evidence that muriate of potash may give good results, looking at it from the standpoint of the grower, but its use is not generally advocated, as it no doubt injuriously affects the burning qualities of the tobacco.

Special Potash Plats. Under these different amounts of potash, both muriate and sulphate, 12, 24, 36, 80, and 160 pounds per acre are used.

So far, the results have shown that from 36 to 40 pounds of potash per acre will show a profit even at a very high cost of material, as high as $1 per pound, but beyond that quantity it does not show the same profit.

Fourteen Plats Using Farm Manures and Tobacco Stems. The results from these tests have shown that good tobacco can be grown by the use of farm manure and hard wood ashes; and also from the use of tobacco stems and phosphoric acid.

Variety Tests of Tobacco. We have tested out a large number of so-called varieties, also a large number of distinct varieties, kept record of yield and color, and have tried to classify as many of these as possible. Up to this time no breeding work with tobacco has been carried on for the lack of time and help.

Rotations—Systems for Tobacco Farmers. We are working on two-, three, and four-year rotations for tobacco, using as many legumes as can be worked in, and have been able to get some results, but conditions on each farm change so much that we are not yet able to determine the best rotation to follow on the average tobacco farms of the State.

Tobacco After Cowpeas. By the use of liberal amounts of phosphoric acid and potash, combined with closer planting and higher topping, we have been able to grow 800 to 1,000 pounds per acre of fairly good tobacco. The usual trouble of leaf spotting and diseased tobacco has not yet been experienced, which frequently follows when tobacco is planted after cowpeas. However, this is not recommended as a very good rotation, as there are other troubles which often follow, viz., wire worm or, possibly, root rot.

Closer Planting Combined with More Intensive Fertilization. In this experiment 12 plats of one-twelfth acre each were used. From 450 to 1,000 pounds per acre of a 5-8-5 fertilizer were used, and from 18 to 36 inches in the row, 45-inch rows, with each of the different applications of fertilizers. The results thus far secured have been very gratifying. By closer planting and better fertilization the yield can be practically doubled and still maintain the quality. It is not recommended, however, as a general proposition, that farmers be advised to use more intensive methods, plant more tobacco on the land, and use more fertilizers.

Experiments in Priming vs. Cutting. These experiments have been discontinued after six years work. The results from four years work have been published in Bulletin No. 238 of the N. C. Experiment Station. About 75 per cent of the farmers of Granville County, and from 40 to 75 per cent of all those in the adjoining counties, have changed their methods of harvesting the tobacco crop from cutting the stalk to priming off the leaves as they mature, since seeing or reading of the results of this experiment. Our estimate, which is in accord with the estimate of a number of the best tobacco men of Oxford and the county, is that this one change in the method of harvesting the tobacco crop has saved the farmers, during the past three years, not less than three or four million dollars.

Permanent Tobacco Seed Beds. It is believed that a permanent seed bed, located at a convenient place, near water, etc., can be established and maintained indefinitely, provided the bed is thoroughly sterilized each year. This is being done at this farm by the use of steam, which has been found to be the most economical, as well as the best method of sterilizing seed beds.

Nutrition Work. In these experiments there are 126 plats being conducted in coöperation with the U. S. Department of Agriculture. These plats are seeded with different legumes, both winter and summer, and are then planted to tobacco, cotton, and corn, after which they are planted to rye, wheat, and oats. The results thus far secured are exceedingly interesting, and will be very valuable as soon as we can get enough data to safely interpret the results and make general deductions. The chief purpose of the experiments is to determine the best legume for each of the three main crops grown in the State, also to determine the residual effects. Ninety plats, under this same project, have now been conducted for four years to determine the effects on the three main crops—tobacco, cotton, and corn—also fifteen plats more as checks on both series, making a total of 231 plats under this project, alone.

In addition to the projects mentioned above, which represent 401 plats to be cared for each year, there have been conducted at the Granville Farm, in coöperation with the Office of Tobacco Investigations of the U. S. Department of Agriculture, a large number of tests in the laboratory for the past two summers, working on the different leaf-spot diseases, "sand drown," and various other nutrition troubles.

However, this is the only tobacco station that is operated on land owned by some permanent organization in the United States, and should therefore be put in the best shape possible to do tobacco work, as tobacco is one of our most important farm products in a financial way. It is true that there is other work on tobacco being conducted in other places, but this is being done mostly on land controlled by short term leases, and with little or no equipment.

In order to put the work in the most satisfactory working condition at this farm, more funds will have to be provided than have been available in the past.

PLANT BREEDING EXPERIMENTS

With Cotton at Central Farm. During the year the breeding work with cotton, with Adams funds, has consisted of a minute study of the plant characters of twenty-six strains of cotton which had been isolated from a strain of King's Improved. This season marks the sixth year that this study has been made. During this time, the strains have been reproduced by self-fertilized seed. Up to 1919 there was no perceptible decrease in the vigor of the different strains due to selfing, but this year there was some evidence of a lack of vigor. Whether or not this was due to external factors, it is impossible to say at this time. Self-fertilized seed have been secured again this year to compare with crosses

between several of the strain. The result by comparison of these crosses will help to indicate the effect of selfing for several years.

During the past two years the highest yielding strain has, on an average, produced 146 per cent greater yield in seed cotton than the lowest yielding strain. In a comparison of the size of bolls of the different strains, No. 43-54-5, the highest yielding strain, produced bolls which averaged 59 per cent more seed cotton than did No. 50-39-5, the lowest yielding strain. The average length of the lint of strain No. 43-54-5 has been 33⅓ per cent greater than strain No. 21-28-74, grown under the same conditions. In a comparison of the percentage of lint to seed, 43-54-5 has averaged 41.2 per cent, which is about 17 per cent greater than the percentage of lint produced by 13-33-5.

Effect of Locality Upon Characters of Cotton. In this work, a comparison of cotton plants grown from Mississippi and North Carolina seed of the same pure strain is being made in coöperation with the Mississippi Experiment Station. The original seed came, in 1914, from one self-fertilized plant of a uniform row in the plant-to-row breeding patch at the Central Farm, West Raleigh. One-half of the seed produced by this plant was supplied to the Mississippi Station and planted there; while the other half was planted at the North Carolina Station during the same season. The results secured in this coöperative work have been prepared for joint publication. The strain of cotton used in the experiment is still being grown, and kept pure in the two localities for the purpose of comparing seed from the two sources after several years growth. Arrangements were made this year for the extension of the work to include the Texas Experiment Station.

The results from the 1917-18 comparisons have shown that seed grown at the Mississippi Station, and brought to North Carolina and planted in alternate rows at West Raleigh, in comparison with seed of the same strain locally grown, have consistently produced taller plants which mature earlier. The difference in height has been noted from the time of blooming to maturity. Plants grown from Mississippi seed of this same pure strain have produced slightly heavier yields, a little longer staple, and are a little earlier in maturity.

CROP IMPROVEMENT WORK

With Cotton in Different Communities. During the past five years twenty-three communities in fourteen counties have received aid in improving their seed cotton for planting purposes. In each case, except one, the communities have been given a better variety than was locally grown up to the time the local test was made. At present, nine growers are improving their seed cotton by field selection and by systematic plant-to-row breeding. The men who are selecting seed, in coöperation with the Division of Agronomy, will have something like 4,800 bushels of improved cotton seed for sale this fall. Efforts are being made to induce the selling of as much of these seed as possible in the localities in

which they were grown. Practically all testing of varieties of different crops has been discontinued, except that which is being done in the community improvement work.

Community Improvement Work with Grains. In this work it is planned to handle corn, wheat, oats, and rye in the same way as cotton improvement work is carried on. Pure strains of each of these crops are now being increased at the Central and Iredell farms. Three communities of farmers have been started during the year in the improvement of their corn, and three have been organized in Gaston County for wheat improvement.

At the Buncombe Farm. On this farm Biggs Seven-ear corn is being selected for the two-ear type, and for increased yield per acre. Growers of the surrounding country are taking advantage of the good seed corn grown on this farm. In recent years the demand has been greater than the supply.

During the past season a small amount of pedigreed Haberlandt soybeans was grown for increase. The strain No. 38 was isolated three years ago from the ordinary Haberlandt. The improved strain matures ten days to two weeks later than the ordinary Haberlandt, and has been found to yield, when grown under the conditions existing on this farm, from six to ten bushels more per acre. This strain of soybeans should be to the mountain section of the State what the Mammoth Yellow variety has been to the coastal plain section. Four bushels of seed from this improved strain have been harvested this season. As soon as enough seed has been produced, it is planned to have this improved strain replace all others on this farm, and to produce each year a surplus of seed to be sold to farmers in the community. The work with soybeans has attracted considerable attention from farmers. The superintendent of the farm has had numerous calls for seed, and for information with reference to the best methods to follow in the growth and handling of the crop.

At the Iredell Farm. At this farm wheat, oats, rye, cotton, corn, and soybeans are being improved in a systematic way.

Each year a seed patch of strain No. 29 of cotton is grown and the best plants are saved for planting the seed patch the following year. At this time the strain is uniform in type and unusually productive when grown in this section. The farm should have between 75 and 100 bushels of seed of this strain to sell to farmers this year.

Beginning with this fall, the entire wheat crop on this farm was planted to a specially selected strain of Leap's Prolific. By next spring the improved Appler oats that are being grown will be sufficiently increased in quantity to plant all the oats on the farm to this specially pedigreed strain. Our pedigreed Abruzzi rye has also been sufficiently increased to plant the entire crop. The best crop of Abruzzi rye yielded at the rate of 26 bushels per acre this past spring, being considerably more per acre than was produced from wheat grown on adjoining land.

Weekley's Improved strain of corn for general crop planting is being kept up to standard by the growth of a seed patch each year on this farm.

During the past spring a small amount of Virginia soybeans, No. 11, was grown on this farm for increase. This strain was selected at the Central Farm three years ago. It has been found to be a high-yielding strain, and not to lodge as badly as does the strain of Virginia from which it came, and which is commonly found on the market. Five bushels of seed of the improved strain have been saved and will be used for increase purposes for distribution in the Piedmont section.

The plant improvement work with small grains at this farm has attracted the interest and favorable comment of visiting farmers. Visitors have been impressed with the superior yielding powers, purity, and uniformity of growth of the selected strains. The superintendent of the farm states that the selected strain of cotton used for planting the general crop is showing a marked influence on the yield and quality of the general cotton crop.

Rosin rye, which has been so extensively advertised in the central west, has not been found to produce satisfactorily on this farm. Abruzzi rye has been found to put out growth much earlier in the spring, and to be of a much more upright habit of growth than common rye. It has, therefore, been found especially suitable for seeding where winter and early spring grazing are of prime consideration.

At the Central Farm. On this farm seed improvement work is being carried on with cotton, corn, soybeans, wheat, and rye. The improved strain of King's Cotton, No. 29, is being kept pure and high yielding by selecting seed from the highest yielding plants, and by growing a seed patch with these seed each year. A selected strain of Mexican Big Boll made a yield of 1,450 pounds of seed cotton per acre, which had a 1⅛-inch staple. Next season it is planned to compare this strain with strain No. 29 of the King type, to determine the relative money value of the yields per acre of the two, in order to choose between the two for future growth on this farm.

A strain of Cocke's Prolific variety of corn is being improved by ear-to-row selection.

Our pedigreed Leap's Prolific wheat, No. 12, has been increased sufficiently to plant the entire crop on this farm this fall, and a portion of it has been used in three community tests out in the State.

One pedigreed strain of Abruzzi rye has also been increased sufficiently to meet the planting needs this fall.

Pedigreed strains of Mammoth Yellow, Virginia, and Haberlandt varieties of soybeans have been selected for increased yields. A portion of the best strain of Mammoth Yellow has been sent to the Edgecombe Farm for increase. One of the strains of the Haberlandt variety has been increased at the mountain farm, and the best Virginia strain, isolated here, has been sent, as mentioned above, to the Iredell Farm for increase.

At the Edgecombe Farm. At this time attention is centered at this farm on the improvement work with cotton and soybeans. Mexican Big Boll is the variety of cotton to which attention has been centered up to the present time. It has thus far proven to be earlier and much more uniform in quality than the original strain of Mexican cotton from which this strain came. If this farm could be equipped with a good gin, seed could be sold from the crop next year.

The strain of Mammoth Yellow soybeans, No. 101, being increased on this farm, was first isolated at the Central Farm three years ago. In comparison with the original strain last year, the selected strain yielded 7.7 bushels more per acre than did the variety from which it came. A pedigreed strain of Virginia soybeans, No. 12, is also being increased here.

In addition to the work indicated above for different farms, corn breeding experiments have been started recently at the Granville and Washington farms.

BREEDING SOYBEANS FOR HIGH-OIL CONTENT

The breeding of soybeans for high-oil content has been continued. The strains which have been found to produce the highest percentages of oil have thus far proven to be the poorest yielders. The largest quantity of oil per acre has been found to come from those strains which have yielded the largest quantity of seed per acre.

COOPERATIVE SMALL GRAIN WORK WITH THE U. S. DEPARTMENT OF AGRICULTURE

In these experiments a comparison of the growth and yields of wheat and oats is made, when planted at different dates and at different rates of seeding.

With wheat, the dates of seeding were October 1, October 15, November 1, November 15, and December 1. The rates of seeding on each of these dates were 30, 60, 90, and 120 pounds per acre.

With oats, the plantings were September 1, September 15, October 1, October 15, and November 1. The different rates of seeding on each of these dates were the same as for wheat.

These tests were carried on with Appler oats at the Iredell and Edgecombe farms, and with Fulcaster wheat at the Iredell Farm. In the test with wheat, during the year 1918-19, the November 1 date of seeding made highest yields of both straw and grain. According to previous tests, the October 15 planting should have stood first. The results from the past year may have been modified to some extent by seasonal conditions, the drouth during the past spring having done less damage to earlier maturing varieties and plantings. In all plantings with wheat, up to December 1, the 60-pound seedings have yielded best. A few of

the higher seedings produced slightly more than the 60-pound seeding, but the yield was not sufficient to warrant the use of the higher rate of seeding.

In the order of yield of seed, the oats ranked as follows during the past year: November 1, October 15, November 15, October 1, and December 1. Among the plantings made November 1, the 120-pound seeding yielded best. The seeding made December 1 did not germinate until the latter part of January. The seeding work with oats at the Iredell Farm showed November 1, during the past year, was the best date. Such results are unusual for this section, but are in accord with those secured with the wheat. The dates of planting ranked, according to yield during the past year, as follows: November 1, November 15, Ocfober 1, and October 15. With the exception of the November 1 seeding, late seedings have yielded best with the higher rates of seeding. The following is a list of the dates, with the rates which produced the highest yields of seed:

October 1	30 pounds
October 15	60 pounds
November 1	30 pounds
November 15	120 pounds

The best yield of straw was produced by the November 1 seeding. The November 15 seeding did not germinate until the latter part of January.

With oats, on the Edgecombe Farm, the November 1 seeding during 1918-19 gave best results. The oats, ranked according to yield per acre, as follows: November 1, October 15, November 15, and October 1. These results, as with wheat, are also contrary to the usual belief that early planted oats yield best. A closer examination of the temperature and precipitation of these two sections may throw light on the causes for the results during the past year. The rates of seeding of oats which yielded best on the different dates are:

October 1	60 pounds
October 15	30 pounds
November 1	90 pounds
November 15	120 pounds

The largest amount of winter-killing occurred on the November 15 seeding, while the October 15 planting showed the least amount of damage from this cause.

In closing, it may be said that the progress of the work of the Division has been due largely to the loyalty and fidelity to duty of those associated with the Division.

Respectfully submitted,

C. B. Williams,
Chief, Division of Agronomy.

REPORT OF THE DIVISION OF CHEMISTRY

To the Director:

It gives me pleasure to submit herewith a report of the Division of Chemistry for the year ended June 30, 1919.

The work of previous years has led to the conclusion that the toxicity of cotton seed is due to the presence of gossypol. In cottonseed meal this substance may be present in unchanged form; may be changed to a nearly related substance, which we have designated as D-gossypol; or may be changed to some other substance. The gossypol, itself, appears to be more toxic than either substance derived from it.

The work of the past year has been performed with the assistance of L. F. Williams, C. F. Miller, and S. J. Marion, members of the staff of the Chemistry Department of the college. For the coming year F. W. Sherwood has been appointed Assistant Chemist, and will give his entire time to the chemical work.

The results may be briefly summarized as follows:

(1) There is no evidence that gossypol or D-gossypol is left in the meal after extraction with ethyl ether and then with aniline, ether dissolving gossypol, aniline both of these substances.

(2) Analysis of the aniline-gossypol compound shows 73.74 per cent of carbon, 5.76 per cent of hydrogen, and 3.85 per cent of nitrogen, while analyses of aniline-D-gossypol show 74.81 per cent of carbon, 6.12 per cent of hydrogen, and 3.89 per cent of nitrogen. These figures, as well as the difference in the solubility in ether, indicate that these two substances are not the same compound.

(3) When aniline D-gossypol is heated to 140 degrees in the air it gains 0.71 percent in weight, while aniline gossypol, under apparently the same conditions, gains 1.96 per cent of its original weight.

(4) Cottonseed hulls have been found to contain 0.75 per cent gossypol, while the meats contain 0.70 per cent gossypol.

(5) Benzidine, aniline, phenyl hydrazine, (p) nitroaniline (p) toluidine, and alpha naphthylamine all produce precipitates, with the gossypol present in crude cottonseed oil, but that produced by aniline is the easiest to handle. This was done in connection with attempts to improve the method for the quantitative determination of gossypol.

(6) A mixture of phenyl-hydrazine and gossypol-free crude cottonseed oil becomes a solid mass of crystals, after standing a few days.

(7) Pure gossypol or D-gossypol does not form precipitates with benzidine, (p) nitroaniline, phenyl hydrazine, (p) toluidine, alpha napthylamine or urea in alcoholic solution.

(8) Free gossypol or D-gossypol in alcoholic solution, forms precipitates with the alcohol soluble proteins of either wheat flour or cottonseed meal.

This, perhaps, partially explains why heating reduces the toxicity of cottonseed meal, assuming that the gossypol or D-gossypol protein compound is not readily digested by the animal.

(9) In general, heating cottonseed meats to various temperatures in atmospheres of different gases, and in the presence of varying amounts of water, decreases the gossypol and sum of the gossypol and D-gossypol present, but increases the amount of D-gossypol content. The greatest effects are shown by oxygen and by carbon dioxide. The results obtained so far have not been consistent in all cases. This line of work seems to offer promise and will be followed up in order to determine the best conditions for mill operatives in order to produce a non-toxic meal.

Respectfully submitted,

W. A. Withers,
Chemist.

REPORT OF ANIMAL INDUSTRY DIVISION

To the Director:

Last year a statement of the investigational projects under way by the various members of the Animal Industry Division were given. Previous to that time, in the annual report I picked out some of the most outstanding features of the Division and reported these features in more or less detail. I will follow my old plan this year, as some have expressed a preference for the old plan. I cannot, of course, attempt to give in detail all of the work of the Division, but I will explain a sufficient number of projects to give a rather comprehensive idea of the work of the Division as awhole.

GENERAL SUMMARY

A general view of the activities of the various offices in the Division may be had from the following summaries:

Name of Office	*No. and Kind of Meetings*	*No. People Attending*	*Letters Written*
General Office (Gray)	1 community fair	320	1,296
	2 institutes	225	
Dairy Extension	2 opening of cheese factory	115	5,400
	3 farmers' institutes	105	
	1 farm life school	50	
	32 farmers' meetings (bull association and buying cows)	978	
	2 Holstein cow demonstrations	190	
	4 creamery stockholders	145	
	1 discussion milk situation	20	
	4 cheese factory annual meetings	117	
	2 promoting cheese factory	200	
	8 cheese factory organization	273	
	3 cattle improvement	130	
	1 directors' meeting	8	
	1 colored agents' meeting	20	
	1 general agents' meeting	100	
	1 butter-making demonstration	75	
	1 Convention Southern Cheese Men	20	
	1 State Dairymen's Association	30	
	1 location of site	65	
	1 distributing Holsteins	50	
Dairy Experimentation			1,248

Name of Office	No. and Kind of Meetings	No. People Attending	Letters Written
Swine Extension	2 club short courses	220	924
	2 farmers' institutes	170	
	1 picnic	175	
	1 farmers' convention	125	
	1 district fair		
	26 farmers' meetings (community)	714	
Swine Experimentation	1 South'n Agricultural Workers		525
Poultry Extension	372 school meetings	22,052	1,269
Poultry Experimentation	12 institutes	441	1,800
	6 poultry schools	243	
Beef Cattle and Sheep	57 demonstrations	1,425	9,463
	15 lectures	1,200	
	1 specialists' meeting	50	
	1 International	25	
	1 South'n Agricultural Workers	500	
	1 wool conference	200	
	1 specialists' meeting	25	
Total	574	30,801	21,925

OFFICIAL PUBLICATIONS BY MEMBERS OF ANIMAL INDUSTRY DIVISION

The members of the Division have not published as much literature this year as previously, but the public has been kept in touch with our various lines of work by means of circular letters, circulars, bulletins, and magazine articles. The following table gives the official publications of the Division during the last fiscal year.

Circular letters, 9 ..... *Curtis*
Circular letters, 1 ..... *Reed*
Circular letters, 14 ..... *Shay*
Circular letters, 1 ..... *Hostetler*
Circular letters, 1 ..... *Combs*

Circulars, 3:
- Beef Calf Clubs ..... *Curtis*
- Sheep Clubs ..... *Curtis*
- Beef Circles ..... *Curtis*

Circulars, 1:
- Score Card for Lard Type Hogs and Colony Hog House ..... *Shay*

Circulars, 1:
- By-products from Meat Curing ..... *Hostetler*

Circulars, 1:
- To Preserve Eggs for Winter Use ..... *Kaupp*

Bulletins, 1:
- Effect of Cottonseed Meal in Reproducing Animals ..... *Curtis*

Bulletins, 2 (posters):
- Sell Milk for the Cheese Factories—Get a Good Cow ..... *Reed*

Bulletins, 1:
- Results of the Guilford-Forsyth Cow-testing Organization ..... *Combs*

Magazine Articles, 13:

Cottonseed Meal as Poultry Feed. Jour. of Inst. & Inv. in Poultry Husbandry ..... *Kaupp*
Abnominal Purulant Condition of the Hen. Jour. Assn. of Inst. & Inv. in Poultry Husbandry.
Sarco-Chrondo-Osteomata of a Hen. Jour. A. Vet. Med. Assn.
General Sarcomatosis of the Fowl. Jour. Assn. of Inst. & Inv. in Poultry Husbandry.
Tendonitis and Periostitis Resulting from Injury by a Celluloid Spirolet Leg Band. A. Vet. Jour.
The Rationing of Poultry. Poultry Item.
Physical Characters Which Correlate with Egg Production. Poultry Item.
Plan of Production of Pedigreed Birds. Poultry Item.
The Three Stages in Handling Poultry. Poultry Item.
Two Years from Purebred Poultry to Mongrels. Poultry Item.
How the Chic Grows in the Shell. Poultry Item.
A Successful Small Commercial Flock. Poultry Item.
The Cost of Keeping a Flock of Fowls Now and 30 Years Ago. Poultry Item.

Books:

The Anatomy of the Domestic Fowl. Pub. Philadelphia and London. *Kaupp*
Poultry Culture, Sanitation, and Hygiene. Pub. Philadelphia and London. *Kaupp*

SWINE EXPERIMENTS

Our swine experimental work is now in direct charge of Mr. Earl Hostetler, who is devoting all of his time to it. As outlined at the present time this work is being done at the Central Experiment Station at Raleigh, at the Edgecombe Test Farm, and at the Iredell Test Farm. On account of the smallness of the Pender Test Farm and the encroachment of the horticultural work upon our space, it was necessary to discontinue all hog work at that place. This was done October 1, 1919.

The Value of a Mineral Mixture in a Hog's Ration

(Central Experiment Farm)

All of us have felt that we appreciate the value of minerals in the hog's ration, but the results of some experimental work we are doing seem to indicate that we have never valued this part of the ration as highly as it deserves. The National Hog Remedy Co., of Raleigh, N. C. had a representative to call upon us and ask us to conduct some feeding experiments to determine the value, if any, of their mixture which goes under the name of the National Hog Remedy and Liver Regulator. This led us into the study of mineral mixtures as supplements to grain mixtures.

On December 18, 1918, fifteen pigs were purchased for the first of these series of experiments. As the above company claimed that their mixture removes intestinal and kidney worms, pigs were selected which were known to be badly infested with worms. The pigs were divided into three equal lots, the first lot being fed a ration made up of one-half corn, one-fourth wheat shorts, and one-fourth peanut meal. The second

lot of pigs was fed a similar ration both as to kind and amount, and the ration was supplemented with a home-made mineral mixture. The third lot of pigs was fed a similar ration, supplemented with the National Hog Remedy and Liver Regulator. The experiment continued through March 16, 1919, a period of 88 days. Each pig in the first lot gained daily .47 of a pound, each pig in the second .68 of a pound, and each pig in the third lot .70 of a pound. When corn is valued at $2 per bushel, wheat shorts at $64 per ton, and peanut meal at $70 per ton it cost $24.96 to make one hundred pounds of increase of live weight in the first lot where no mineral mixtures were used, $16.38 in the second lot where the home-made mineral mixture was used, and $16.36 in the third lot, where the National Hog Remedy and Liver Regulator was used. It should be stated, however, that these mineral mixtures used in the first experiment played an active part in removing the worms from the intestinal tract and from around the kidneys, but as the second experiment is just being closed, the report of this part of the work is withheld until a post mortem examination is held on the second lot of pigs.

The mineral mixture used was made up of:

Crushed charcoal	10 pounds
Air-slaked lime	5 pounds
Salt	4 pounds
Sulphur	2 pounds
Copperas	3 pounds

The second experiment was begun June 14, 1919, and closed November 3d, covering a period of 142 days. The first three lots in this experiment were fed exactly the same amount of grain, notwithstanding the fact that the two lots receiving the mineral mixtures would have eaten very much more grain than the first lot, which ate grain alone. The last two lots, four and five, were fed all of the grain they would eat in addition to the mineral mixtures. The pigs in lot one were fed a ration made up of one-half corn, one-fourth wheat shorts, and one-fourth peanut meal; these pigs gained daily .33 of a pound at a cost of $23.76 per hundred pounds. The second lot of pigs was fed a similar grain ration plus a mineral mixture like the one used in the first experiment; these pigs gained .43 of a pound daily at a cost of $18.22 per hundred pounds. The third lot of pigs was fed a grain mixture equal to that in the second lot plus the National Hog Remedy and Liver Regulator; these pigs gained daily .42 of a pound at a cost of $19.02 per hundred pounds. The fourth lot of pigs ate all of the grain mixture they wanted, plus the home-made mineral mixture; these pigs gained daily one pound at a cost of $16.74 per hundred pounds. The fifth lot of pigs ate all of the grain mixture they wanted plus the National Hog Remedy and Liver Regulator; these pigs gained daily 1.15 pounds at a cost of $17.10. At this writing post mortem examinations have not been held, so we are not ready for this part of the report.

Fish Meal Against Tankage as a Feed for Hogs

(Central Station)

During the last two years many inquiries have come to us relative to the value of fish meal as a feed for hogs when used in conjunction with corn. The value of tankage is so well known that we thought it would be well to compare fish meal directly with tankage. Consequently, an experiment was outlined and begun April 23, 1919, to determine the relative value of these two meat products. The first experiment was closed August 20, 1919, so the experiment continued 119 days. The pigs were divided into two lots, the first lot being fed a ration made up of nine-tenths shelled corn, plus one-tenth Digester Tankage, while the second lot had fish meal substituted in the place of tankage. The average daily gain was almost the same. The tankage-fed pigs gained .95 of a pound each daily, while the fish meal fed ones gained exactly one pound each, daily. When shelled corn is valued at $2 per bushel, tankage at $110 a ton, and fish meal at $100 per ton, it cost $20.10 to make one hundred pounds increase in live weight in the tankage-fed lot, and $18.86 to make an equal increase in live weight in the lot where fish meal was used. This experiment would seem to indicate, therefore, that fish meal has an important place to fill in a hog's ration.

Curing Meat on the Farm

(Pender Test Farm and Central Experiment Farm)

We are doing no little amount of work to determine the best methods of curing and smoking meat under farm conditions. In this study we are determining the shrinkage in meat during the curing processes, shrinkage of meat when made from meat of hogs which have been fed upon different rations, and shrinkage of meat when cured by various patent processes, and the effects of feeds and patent processes upon the keeping of the cured meats. Almost all of this work is being done at the Central Farm as it requires the constant attention of Mr. Hostetler. The manufacturers of patent liquid smoke usually claim that the shrinkage of meat is very much less under their treatment than when hickory smoke is used. This year the meat cured by the liquid smoke method shrank 13.9 per cent in weight, while that cured by the hickory smoke method shrank 14.9 per cent in weight. We have accumulated results for five years, and the average shows that the shrinkage when liquid smoke was used was 12.7 per cent, while the shrinkage when hickory smoke was used was 12.9 per cent. The claims of the manufacturers of liquid smoke are not, therefore, justified.

Packers usually make the claim that meat made from hogs which have been fed upon soybean and peanut pastures shrink very much more during the process than meat cured from hogs fattened upon corn alone. In fact, this is one of their main arguments for discriminating against soft-bodied hogs. Our results for the past several years do not bear out

the packers' charge. In our work meat cured from hogs which never had peanut or soybean pasture shrank 19.4 per cent; cured meat from hogs which were grazed upon soybeans shrank 20.6 per cent; meat made from hogs fattened upon peanut pastures shrank during the curing process 16.9 per cent.

Arrangements are made to enlarge very materially our capacity for studying such problems as these in the future.

Grazing Crops and Soft Pork

(Edgecombe and Central Test Farms)

Mr. D. M. McCarty, chemist for the Animal Industry Division, secured leave of absence and enlisted in military services at the beginning of the war. It has been impossible, therefore, for us to take care of the chemical part of the soft pork studies. We have, however, preserved samples from all of the animals and will be ready for the chemical work just as soon as another chemist can be secured. Unfortunately for us, Mr. McCarty is not coming back, as he has decided to farm in Mississippi. We hope, however, to get a good chemist within a short time.

We have continued the study of the problem to determine the relative value of peanuts and soybeans, and also to determine just how much grain, if any, should be used as a supplementary ration to these pastures. This year one experiment began October 10th, and continued until December 6th. During this time the lot of pigs in the dry lot were fed upon a ration made up of two-thirds corn, and one-third wheat shorts, and gained daily .32 of a pound at a cost of $35.25 per hundred. The second lot of pigs was fed a similar ration in conjunction with soybean pastures; these pigs gained daily .46 of a pound at a cost of $22.39 per hundred. The third lot of pigs was fed upon soybean pastures alone; these pigs gained daily .41 of a pound at a cost of $20 per hundred. The fourth lot of pigs was fed peanut pasture alone; these pigs gained .62 of a pound at a cost of $23.80 per hundred. The pastures were very poor, as the cost of gains would indicate. In the above financial statement, corn is valued at $2 per bushel, wheat shorts at $58 per ton, and pasture at $20 per acre. The primary object of this study, of course, is to get samples of lard to determine the effect of these feeds upon the bodies of the animals. These samples were secured and will be studied just as soon as a chemist is located.

The second experiment was conducted at the Pender Test Farm, to study further the relative value of soybean and peanut pastures. This test was under way from October 28th to December 19th, a period of 52 days. The pigs in the first lot were fed a ration made up of two-thirds corn, plus one-third wheat shorts; these pigs gained .46 of a pound daily at a cost of $25.71 per hundred. The pigs in the second lot were fed a half ration of corn and shorts as a supplement to soybean pasture; these pigs gained .46 of a pound daily at a cost of $25.50 per hundred.

The third lot of pigs was fed a similar grain ration as a supplement to peanut pasture; these pigs gained .9 of a pound daily at a cost of $13.43 per hundred. Samples of lard were also taken from these animals and will be preserved for the chemist.

We are continuing the investigation relative to the value of bur clover pasture as a grazing crop for pigs during the spring months. This year the grazing continued from March 28 to May 15th, a period of 48 days. One bunch of pigs was maintained in a dry lot upon a ration made up of two-thirds corn plus one-third wheat shorts; each pig gained .17 of a pound daily on a grain ration of 1.89 pounds each. The pigs in the second lot—17 on one acre of bur clover—gained .17 of a pound daily on a daily grain feed of 1.03 pounds each. Each acre of bur clover, therefore, saved $21 worth of grain, and did this in 48 days.

We have recently inaugurated some work at the Edgecombe Test Farm to determine the exact value of permanent pastures when used as grazing areas for hogs. The first test was inaugurated May 27th and continued to September 16th, a period of 112 days. The first lot of hogs was fed in a dry lot on a ration made up of two-thirds corn plus one-third wheat shorts; these pigs ate daily 2.94 pounds of grain and gained .42 of a pound daily. The second lot of pigs was fed a similar but smaller ration of grain as a supplement to the Bermuda pasture; each one of these pigs ate daily 2.46 pounds and gained .41 of a pound. An acre of Bermuda therefore saved, during the 112 days, $9.03 worth of grain, when corn is valued at $2 per bushel and wheat shorts at $60 per ton. This study is to be continued for a number of years.

POULTRY INVESTIGATION

Dr. Kaupp, who has charge of this office, is assisted by Mr. Ivey and Mr. Warden. As in the past, his work has consisted almost entirely of investigational work, but he does a small amount of extension work when a phase of extension activity comes up that cannot be handled by the regular extension men.

COOPERATIVE COMMERCIAL WORK

During the war Dr. Kaupp was called upon by some of our neighbors to assist in commercial enterprises. He always did this whenever the one asking the assistance agreed to place the business upon such a basis as to give him financial and other results. This sort of work was carried on with Mrs. Jesse Earnshaw of Wake Forest, N. C., in an undertaking to grow baby chicks; with Mr. L. J. Banzet of Ridgeway, N. C., in an undertaking where the selling of eggs was the main product; with Mr. M. Lienn of Apex, N. C., with a small undertaking; with Mr. C. P. Wharton of Raleigh, N. C., in a city back lot enterprise, and with others. Dr. Kaupp, through these efforts, was able to be of material assistance to some farmers, and gained a lot of commercial information which has been of assistance to him in his educational campaigns.

EXPERIMENTAL WORK

The investigational work done by this office is divided into two heads. Dr. Kaupp is a pathologist, so he necessarily devotes much of his time to pathological studies. The rest of his time is devoted to feeding and nutritional studies.

A. PATHOLOGICAL STUDIES:

The specimens coming to the laboratory determine in a measure the kind of pathological work done. During the year he has had occasion to study further cases of white diarrhea in chickens, liver and kidney troubles, diseases of the reproductive organs of the hen, diseases of the lungs of fowls, diseases of the shell glands, tumors of the ovaries, bleeding combs of hens, and other pathological studies. Almost all of these studies have been reported in the scientific journals of this and other countries.

B. FEEDING AND NUTRITIONAL WORK:

(*a*) *Cost of Raising Chicks.* We raised twenty flocks of chicks at the Central Plant during the past year, and kept an exact count of the feed eaten and cost of the feed, and the weight of the chicks at various ages. The average weight at the end of eight weeks was .82 of a pound. It required an average of 3.2 pounds of grain and 3.2 pounds of buttermilk to produce a pound of gain. At prevailing prices of feeds the cost of the feed was 20 cents a pound, which represents about 50 per cent of the total cost of raising chicks during 1919.

(*b*) *Breeding Work with S. C. White Leghorns.* This work is now entering its sixth year. The flock with which we started laid an average of 89 eggs. These hens, known as lot 1, were bred the first year to common cockerels and produced lot 2. The hens in lot 2 laid an average of 92 eggs per year as an average for three years. The hens in lot 1 were then mated to good cockerels and produced the lot of hens called lot No. 3. The hens in lot No. 3 have laid an average of 135 per year for the first two years. This seems to show that high fecundity is transmitted from sire to daughter, although this is sometimes denied by poultry breeders. To determine if high fecundity is transmitted from the sire to the son and the sire to the daughter, brothers of the pullets in lot No. 3 were mated to lot No. 2, and these offspring laid an average of 112 eggs per year for the first year. In addition to studying some of the scientific principles of breeding work, we are developing a flock of hens which are high egg producers. This principle is being applied to the flock of Rhode Island Reds and to the third flock of Barred Plymouth Rocks.

(*c*) *Effect of Temperature, Sunshine, and Barometric Pressure on Egg Production.* Full records are being kept of temperatures, sunshine, and barometric pressure, and these are studied in connection with the number of eggs produced by the various flocks. Long rainy spells regu-

larly depress the egg-laying capacity of flocks. In one long rainy spell the flock dropped 50 per cent in egg yield. The number of hours of sunshine has a bearing on the number of hours the chick can eat, and the number of hours she can eat has a direct bearing upon what she will produce. With this thought in mind, a coöperative experiment has just been put under way with the Manitobia Agricultural College so that we may determine just what influence the number of hours sunshine has upon the egg yield. It may be that the south has a peculiar advantage in this respect.

(*d*) *Does Turning of Eggs Affect the Hatching Qualities?* A number of eggs were set aside for this work, half of the eggs being turned once a day, while the other half was allowed to remain in one position in the box. Four hundred eggs were used in the test, and the result of four tests does not seem to teach that the turning of eggs has anything to do with their hatchability. This is contrary to common opinion, but seems to be true nevertheless.

(*e*) *The Relative Value of Proteins in Growth and in Egg Production in S. C. White Leghorns.* This experiment was outlined to study the value of the sources of protein. The sources of the proteins are found in buttermilk, meat scrap, dried blood, Digester Tankage, soybean meal, and peanut meal. The studies so far lead us to make the following statements:

Birds grow off rapidly with blood meal, and the mortality is less than with any other protein carrier used. At the end of the sixteenth week the chickens raised on buttermilk weighed slightly more than those raised on any other protein carrier. Although the lot receiving blood meal began to lay earlier than any of the others. The first period of this experiment will be concluded October 31, 1920, when a detailed report will be given to the public.

(*f*) *Skim Milk in the Ration for Raising Chicks.* At the Iredell Station a study is being made to determine the value of sour skim milk in the ration for chicks. One lot of chicks is fed a ration made up of corn meal, ground oats, soybean meal, and meat meal. The second lot is fed the same grain ration as supplement to sour skim milk. During this year the chicks in the lot receiving skim milk weighed 1.32 pounds each when eight weeks old, and 3.7 pounds each when sixteen weeks old. Each chicken in the lot where no skim milk was fed weighed at the end of eight weeks .7 of a pound, and at the end of the sixteenth week 2.9 pounds. At the Edgecombe Test Farm a similar study was made, only the grain ration was made up of corn meal and peanut meal. One lot of chickens was fed a grain mixture as a supplement to sour skim milk, and each chicken at the end of eight weeks weighed .91 of a pound, and at the end of sixteen weeks 3.45 pounds. Each chicken in the lot where no skim milk was used weighed .87 of a pound, and at the end of the sixteenth week weighed 2.07 pounds.

(*g*) *Value of Velvet Bean Meal in the Ration for Growing Chicks.* Six separate experiments have been conducted during the year to determine the place of velvet bean meal in the ration for growing chicks and for fattening older birds. Satisfactory results have not been secured in any case. In fact, it seems to be injurious, and we have about concluded the injurious material may be in the pod. Peanut meal is satisfactory. Further studies will be made.

(*h*) *Mineral Requirements for Growing Birds.* One of the most important problems under study by Dr. Kaupp is the one having to do with mineral requirements of growing birds. The first publication of the results is now in press. A summary of this publication may be stated as follows:

1. It is noted in the analyses of the bodies of birds at different ages in their life, beginning when first hatched, that as the bird grows larger that the quantity of calcium, magnesium, and phosphorus is increased. As the bird grows there is a greater proportionate amount of bony structure. There is also an increase of sulphur, due to the fact that as the baby chick grows its downy coat is changed to a coat of feathers. There is also an increase in chlorine.

2. In these studies seventy-three complete mineral analyses of feeds were made, besides analyses of excreta.

3. In the first tests the experimental birds were given grain mixtures consisting of oats, corn, and wheat. The mash contained wheat middlings, bone meal, meat and bone meal, and corn meal. In addition, they were given all the sour skim milk they would drink, finely cut green feed in the form of rape, also oyster shell and limestone grit. In a study of the balances from the table of intake and outgo, there appears ample potassium, sodium, calcium, sulphur, chlorine, and iron, but a slight deficiency of magnesium and phosphorous.

4. Feed mixture 1 has a nutritive ratio of 1:3.2; 3, 1:2.2; 2, 1:7.4; and 4, 1:7.6, which, from a protein carbohydrate standpoint, should be ample. It contained approximately a mineral balance. There was required to produce one pound of gain 2.91 pounds grain and mash, 7.49 pounds sour skim milk (reduced to dry matter would be 0.74 pound), or a total of 3.75 pounds feed.

5. The feeds here studied which are richest in calcium are oyster shell, limestone grit, soybean meal, velvet bean meal, meat and bone meal, bone meal, and eggs in shells. Those richest in magnesium are oyster shells, limestone grit, peanut meal, soybean meal, velvet bean meal, meat and bone meal, bone meal, and wheat middlings. Those richest in phosphorous are eggs in shells, peanut meal, soybean meal, velvet bean meal, meat and bone meal, oats, bone meal, wheat middlings, corn, and wheat. Iron does not appear to be deficient in most feeds. Chlorine is most abundant in eggs in shells, velvet bean meal, and in meat and bone meal. Sodium is most abundant in eggs in shells, peanut meal, soybean meal,

meat and bone meal, bone meal, and wheat middlings. Most cereals and their by-products are deficient in chlorine, sodium, and calcium. Potassium does not appear to be deficient in any of the feeds.

6. Feed mixtures, such as grains and their by-products, need such feedstuffs as meat scrap, bone meal, meat and bone meal, milk, and oyster shell and limestone grit, with one per cent sodium chloride to make good the deficiency in phosphorous, magnesium, calcium, chlorine, and sodium. Of the vegetable products both soybean meal and peanut meal are particularly rich in sodium, potassium, and magnesium. The excellent results which have been obtained by these two feeds are, in part, due to this fact.

7. In feed mixtures 5 and 6 we have introduced the most simple mixtures which have given very gratifying results in those tests where these feeds were given with milk. There is here a fair amount of the most vital minerals, besides essential amino acids, the only mineral deficient is chlorine, which can be compensated for largely by adding three-fourths per cent sodium chloride. These mixtures consist of but two feeds, viz., corn meal with, in the one case, soybean meal, and in the other, peanut meal. In mixture 7 the mineral and protein deficiencies are compensated for by the meat and bone meal. It would be expected that better results would be attained by mixture 8, which has, in addition to the fat extracted, soybean meal, bone meal, and meat and bone meal. Ground oats is added in mixtures 9 and 10, which no doubt adds to the palatability and lends a greater variety.

8. Mashes or ground feed mixtures are essential in chick raising to furnish sufficient mineral salts, which are essential for proper growth. In tests with feed mixtures 5 to 10, the chicks were allowed the run of the grassy yards and were not given grain mixtures. The mortality was not greater than other tests where grain mixtures were fed. It is not essential to give grain mixtures where chicks run at large and can secure bugs, waste grain, and other feeds.

9. In nine flocks of Single-comb Rhode Island Red chicks given mixture 7, with milk and with milk to drink, the average weight per chick at the age of eight weeks was 1.33 pounds, while eight flocks given the same feed, but did not receive milk, averaged 1.15 pounds each. The milk lot averaged 13 per cent greater in weight than the water lot. This difference in weight is due partly to the increased mineral required. The fat remaining in the skim milk furnishes needed fat soluble vitamine, and the milk also contains suitable proteins.

10. Nine flocks of Buff Plymouth Rock chicks were given mixture 10, with milk and with milk to drink. These birds averaged, at the end of eight weeks, 1.30 pounds, while four flocks given the same mixture, but no milk to drink, averaged but 0.88 pounds each. The milk lot averaged 47 per cent greater in weight than the water lot.

11. Twenty-two flocks of White Plymouth Rock chicks were given mixture 9, with milk and milk to drink, at the end of eight weeks these

chicks averaged 1.03 pounds each, while five flocks given the same feed, but no milk, averaged 0.65 pounds each. The milk lot averaged 58 per cent greater in weight than the water lot.

12. The results thus far show greater development in those birds receiving nearer the required amounts of mineral matter. These are the ones receiving animal feeds, as bone meal, meat and bone meal, meat scrap, or milk, together with green feed and crushed oyster shell and limestone grit.

BEEF CATTLE EXPERIMENTAL WORK

(*a*) *Effect of Cottonseed Meal on the Reproductive Ability of Cows.* This is one of the most important and extensive pieces of investigational work being done. It is being conducted by Messrs. Curtis and Combs at the Central Test Farm at Raleigh. This work was started several years ago on a small scale, but has been recently materially enlarged. The plan of the work calls for five lots of animals, the last lot of which is to receive no cottonseed meal at all, and the other lots to receive various amounts of cottonseed meal. A record is being kept of the breeding qualities of all of the animals. An experiment of this kind will necessarily be continued for a number of years, as the offspring of the cows are to be kept and fed just as the mothers are fed. The work has not continued long enough as yet for definite results to appear.

(*b*) *The Effect of Various Roughage Feeds on Retarding the Toxic Effect of Cottonseed Meal in Sheep.* Cottonseed meal is a standard feed of the South, and is well suited to sheep. An experiment was therefore planned to determine whether it can be fed continuously to breeding ewes without ill results. During the summer the sheep are maintained on pasture. During the cold months they are divided into two flocks, one of which is fed cottonseed meal with dry roughage, and the other flock cottonseed meal with succulent roughage. This work has been conducted for four seasons, and up to date no detrimental results have been experienced when as much as two-thirds of a pound of cottonseed meal was fed to each animal daily. There are some indications, however, that cottonseed meal does cause ewes to lamb somewhat early. This may, however, be merely a coincident.

(*c*) *Study of Milk Sickness or Trembles.* The progress and results of this work were published fully in Technical Bulletin No. 115. There are additional phases to be studied, but the war situation delayed pursuing these studies. It is hoped, however, that we may get back to them the coming spring. Plans are made now to demonstrate the usefulness of the results of this research in two or three places in the mountains.

(*d*) *Wintering Stockers and Feeders in the Mountains of North Carolina.* This coöperative work with Mr. T. L. Gwyn of Haywood County is progressing satisfactorily. The past year, from December 12, 1918, to April 17, 1919, five carloads of cattle were used in the experiments. Briefly, the results show that cattle wintered on hay, corn

silage, winter pasture, stover, and straw winter approximately equally well. The cost of wintering varied from $5.52 to $11.88, depending upon the ration used. The cattle in the lot on winter pasture only cost approximately one-half as much as those which were wintered on grains and roughages. All results, as in the past, are very much in favor of the development of winter pastures in the mountain territory.

(*e*) *Residual Effect of Winter Feeding on Subsequent Summer Gains on Pasture.* This work is also being done with Mr. T. L. Gwyn, and is really a continuation of the winter work reported above. The same five carloads of cattle were used, being carried on pasture from April 17, 1919, to September 3, 1919. When the summer and winter work are combined, the results show directly the value of winter pasture. The total cost of the cattle which were carried on pasture both winter and summer was $6.36 less per head than the cattle which were fed during the winter months on hays and other roughages. When winter and summer pastures are taken together, our results have always been in favor of this combination.

DAIRY EXPERIMENTATION

During the year Mr. Combs has devoted much time to tabulating the data previously secured, and getting it ready for publication. Early in the year Bulletin No. 249 was published, giving the results of the Guilford-Forsyth Cow Testing Organization.

COST OF MILK PRODUCTION

In July, 1915, we began a study in coöperation with the authorities of Washington to determine the cost of producing milk upon typical North Carolina farms. The study was made in and around Greensboro, Mr. Combs being in charge. The work closed some time ago, and Mr. Combs has spent much time in getting together this voluminous mass of material for publication. It is ready for publication now, and very much valuable information is coming from the effort. A brief summary of the bulletin shows that the following amounts of labor and feed were required to produce one hundred pounds of milk (it should be remembered that this is an average of more than a dozen herds maintained under farm conditions).

52.9 pounds concentrates.
56.8 pounds dry roughage.
132.4 pounds succulent feed as silage.
11.2 cents worth pasture.
.4 cents worth bedding.
3.4 hours human labor.
1.8 hours horse labor.
55.0 cents overhead cost for production and distribution
51.7 cents credits other than milk.

When grains are valued at $70 per ton, dry roughage at $40 per ton, silage at $10 per ton, human labor at 35 cents an hour, and horse labor

at 20 cents an hour, it cost these farmers just about 60 cents a gallon to produce and deliver their milk. This is perhaps the most accurate information ever secured on the cost of producing milk under actual farm conditions.

EXPERIMENTAL CHEESE WORK IN WATAUGA COUNTY

Early in the spring the Cove Creek Cheese Factory asked the Dairy Experimental Office to determine whether or not a whey separator could be profitably used under their conditions. Mr. Combs secured the loan of two standard machines, installed them in the factory, and spent the greater part of August supervising the investigation. He found that he was able to recover from eight to nine pounds of cream from each two thousand pounds of whey. The labor required to run the whey through the separator amounted to about one hour a day. As the cost of the separator is just a little over $400, he concluded that the machine was practical. The factory therefore decided to purchase a machine and install it for permanent use. It is expected that this will spread to the other cheese factories in the mountains.

PENDER HERD

Before undertaking dairy investigational work with the milking cows in the Pender herd, Mr. Combs decided to set aside a year to develop the herd along breeding lines, and get as many cows as possible in the Register of Merit. During the past year he has succeeded in qualifying fourteen cows, and others are on the Register of Merit test. I have before me now the milk yield of eleven of these cows, the average being 7,413.5 pounds. The average yield of the whole herd the past year has been considerably over 6,000 pounds. There is no reason why this yield, although it is a good one, should not be materially raised during the next year, as several more cows are coming into milk soon. Just as soon as Mr. Combs has developed the individuals of the herd a little further and becomes personally acquainted with the individuals, he expects to undertake our old lines of careful investigational work with them.

Respectfully submitted,

DAN T. GRAY,
Chief, Animal Industry Division.

REPORT OF THE DIVISION OF ENTOMOLOGY

To the Director:

I submit report on the operations of this Division on investigation projects for the year 1919. The year has been one of unusual activity. For several years we have made only brief reference to many projects,

but now we are able to refer to some published results, and to say that others are so far advanced that publication already is, or soon will be, justifiable.

POTATO SPRAYING

With Late Potatoes. This work with late potatoes has been conducted at the Mountain Branch Station by Mr. R. W. Leiby, with the valuable coöperation of Mr. S. C. Clapp, superintendent of the farm. The sixth year of this work has been completed. The past year showed a gain of 53 bushels per acre, or 49 per cent, by spraying with the home-made poisoned Bordeaux mixture, prepared and applied after the manner which we have long recommended.

Bulletin No. 254 of the State Department of Agriculture (March, 1919), prepared by Mr. Leiby, gives the complete tabulated results of five years work on this project. This bulletin has been widely distributed, not only through the regular mailing list, but also to a special list of commercial potato growers, which we worked up for the purpose, in advance of publication. As far back as 1917, we were seeking names and addresses of potato growers—to these a preliminary circular on the subject was sent (Extension Circular No. 48), and they have now been supplied with the complete bulletin.

A very brief tabulation from the summary of results set forth in the bulletin follows:

POTATO SPRAYING—LATE CROP

Average of 5 years experiments, on basis of 1 acre.

Treatment	Yield (Bushels) per Acre	Per Cent Gain per per Acre	Net Money Gain per Acre (Deducting Costs)
1. Check—no control of pests	89.90		$
2. Hand-picking of beetles	98.50	.95	4.82
3. Bordeaux mixture without poison	124.90	39.00	33.22
4. Poisoned Bordeaux (home-made)	141.50	57.50	47.17

With Early Potatoes. The second year of experiments in the eastern part of the State with spraying and dusting has been completed. Tests were made at New Bern, Wilmington, and Mount Olive. Increases varying from 50 to 191 per cent were secured; but as the experiments are expected to run for several years, we would prefer not to publish any elaboration of the results at this time.

LARGER CORN STALK-BORER

The fifth year of work on this has been completed. The data secured on the life history and control of the pest are now sufficiently full to justify publication. They have been assembled in manuscript form with numerous illustrations.

Experiments show that the mortality among the over-wintering borers is greatly increased by plowing the stubble in the autumn. Injury is further reduced by planting May 25th, or later, as corn planted after (about) this date is attacked by only one generation of the borers, while that planted earlier is subject to attack by two generations.

DUSTING OF LATE CABBAGE

This work has been under way for three years, and it is found that weekly dusting with arsenate of lead and air-slaked lime in the proportion of 1 to 8 will control cabbage worms:

	Per cent of Plants Maturing Heads
1. Checks, not dusted	28 per cent
2. Dusted, weekly	75 per cent

We figure that an expenditure of about $6 per acre in this work brings an increased return varying from $50 to $175 per acre in value of product, according to the market.

PECAN INSECTS

This comprehensive project, involving the study of many different insects, has already been well advanced by Mr. Leiby in previous years, and is gradually nearly the point where publication will be justified. The work on this project this year was hampered by the intrusion of new issues.

FIELD STUDIES OF BLACK CORN WEEVIL

This pest has not been especially serious during the year. We continue, however, to note the field conditions which have a bearing on the pest and its control. We have lately seen a single corn-house in this State holding about 25,000 bushels of corn, virtually surrounded by thousands of acres of growing corn. It can be imagined what the weevil problem might amount to in such cases. Hence, every factor in growing, handling, or harvesting the crop previous to final storage, which might influence the number of weevils, becomes important.

INSECT SURVEY

This Division is increasingly impressed with the value of work on this project. Begun 19 years ago, without special reference to its economic bearings, and continued through the years for the sake of the greater grasp and understanding which it gives of the whole group of insect forms, again and again helpful preliminary data on important economic species in our card-records have been found, and data supplied to workers in other states or in the Federal service, on insects whose occurrence, or range, was in doubt. Preliminary data on the worm in soybeans was a recent conspicuous example.

During the year 1919 (to November 20th), 147 species of insects not before known to occur have been listed from the State, bringing the total State list to 5,191 species. The time has fully arrived for the engagement of a skilled worker upon this special project.

GREEN CLOVER WORM ON SOYBEANS

This was a new project of the year 1919. There was a very severe outbreak in July and August, involving thousands of acres. The injury was greatest in the eastern half of the State. A search of publications revealed nothing that could meet the situation. Investigations of intensive character were at once begun at two field stations, at Terra Ceia, by Mr. Leiby, and at Elizabeth City, by Mr. Sherman. Our studies on life-history confirmed much that had been published by others, and yielded much original data of our own. The work on control showed the use of poisons to be effective and more practical than had been supposed; especially when the crop is grown in rows. Dusting with dry arsenate of lead, mixed with dust lime in proportions of 1 to 8, gave the key to the situation. Liquid spraying can also be done. The general principles are similar to those for control of potato beetles or cabbage worms on large acreages. The susceptibility of different varieties, the action of natural parasites, etc., were studied carefully. The data are sufficient to make an important publication, containing much strictly original matter.

ARMY WORMS

Just before the worm on soybeans began its ravages, the Fall Armyworm came into prominence in several localities, and during the soybean epidemic the True Army Worm broke out in grass and corn fields, often adjacent to bean fields, and close to our field stations. Studies were therefore made, incidentally, of the True Army Worm, and data was secured in regard to its parasites, which, when coördinated with similar data obtained in 1908 and 1914, gives a very good body of facts. Any adequate study of this pest must include the study of its parasites, as these are nature's own remedy, and an effective one, never, in our experience thus far, permitting two successive destructive generations of the True Army Worm.

INVASION OF STATE BY COTTON BOLL WEEVIL

It is proper here to record the fact that the cotton boll-weevil invaded North Carolina by its natural powers of spread in the autumn of this year (1919). It has been located at several places in the four extreme southeastern counties of Brunswick, Columbus, Robeson, and New Hanover. This will necessitate an extra amount of scouting and extension work, for which a special worker would be desirable.

ACKNOWLEDGEMENT

Finally, I have, as in previous reports, to gratefully acknowledge the faithful, loyal, and efficient services of each and every worker of our Division, as well as the kind support always accorded by yourself.

Respectfully submitted,

FRANKLIN SHERMAN,
Chief, Division of Entomology.

REPORT OF ENTOMOLOGIST

To the Director:

I beg to submit, herewith, a brief report on Entomology for the past year.

The main project carried on during the past year has been a study of the Leafhoppers of the State. In this work we have had the able assistance of Dr. Herbert Osborn of the Ohio State University, the recognized American authority of this group of insects. Dr. Osborn and I spent most of July, August, and September studying these insects in the fields at two field stations: Wilmington and Swannanoa. A great mass of data was collected during this time, which is being worked up as rapidly as time will permit. In addition to the usual field studies carried on, a great deal of work has been done on these insects. In addition to the usual life history and field studies, we have been indexing and cataloging the literature on this group of insects. This work has progressed very satisfactorily during the year, and is about half completed. The Entomologist has devoted considerable time to the identification of leafhoppers for other entomologists in various parts of the world. Large collections have been studied from South Dakota, from Nebraska, from the Phillippines, from Columbia, South America, and from the French Guiana.

The work on the gloomy scale has been completed, except for a few minor points, and the data accumulated in these experiments is about ready for publication.

Experiments on the life history and control of the tobacco flea beetle have been carried on in the eastern tobacco section, and a bulletin giving the results of this work has been issued as Bulletin No. 239, "The Tobacco Flea Beetle." It is our purpose to continue these experiments in the old tobacco belt, in order to determine in what way it will be necessary for us to modify our recommendations for dealing with this pest in the regions where tobacco has been grown for a number of years.

The corn root worm experiments have been continued at Willard, Wenona, Kingsboro, and Raleigh. The experiments are carried on in coöperation with the Division of Cereal Insects, United States Bureau of Entomology, and it is our expectation to continue them for several years.

The life history studies of the pea and bean weevils are being continued, but no new facts of special importance have been developed.

Respectfully submitted,

Z. P. Metcalf,
Entomologist.

REPORT OF THE DIVISION OF HORTICULTURE

To the Director:

I herewith submit the report of the experimental work of the Division of Horticulture for the fiscal year ending June 30, 1919.

The experimental work of the Division is being continued along the lines of the projects described in previous reports. Some phases of the work conducted have been in progress for a sufficient number of years to furnish data, which are being arranged for publications.

Several additional projects have been added during the year.

The experimental work of the Division was greatly handicapped in the early part of the year, due to the limited number of workers available. Throughout the war period it was not possible to secure competent men to fill the vacancies that existed.

During the latter part of the year, however, the vacancies were filled, and the Division is now in a position to adequately conduct the investigations in progress.

Mr. L. H. Nelson was appointed Assistant Horticulturist in April for work in vegetable culture. Mr. J. M. Dyer was appointed Assistant Horticulturist in September for work in Pomology.

EXPERIMENTAL WORK IN POMOLOGY

1. *Variety Work in Pomology.* (C. D. Matthews and J. M. Dyer.) Notes and observations, on the behavior of varieties of fruits in the different sections of the State, are made from year to year. These notes and observations show the range of adaptability of the varieties in different sections.

Much time and care is expended each year in writing, revising, and checking descriptions of almost all of the important varieties of fruit grown in the State. These descriptions are to be used in future publications, and are employed by the Division as an aid in identifying varieties of fruit sent to the office from over the State.

2. *Native Fruits of North Carolina.* (C. D. Matthews.) The place of origin, the history, and the description of a number of varieties of North Carolina origin have been secured. When opportunity offered, the descriptions of varieties secured previous to this season were verified. Paintings and photographs have been made of the most important varieties.

3. *Investigational Work with Peaches* (Mountain Station, Truck Station, Piedmont Station, Coastal Plain Station). (C. D. Matthews and J. M. Dyer.)

(*a*) *"Dehorning" Peach Trees.* During this last season additional progress with the peach "dehorning" project has been made. From the results so far secured, it has been shown that in years, when the buds are killed by cold, "dehorning" is a profitable practice in renewing old trees. It has been found that the operation may be done relatively late in the spring with satisfactory results.

(*b*) *Peach Breeding.* It is the object of this project to produce improved commercial varieties that are more suited to North Carolina conditions, than are the present varieties. It is the purpose, also, to produce varieties hardier in bud than the present commercial kinds.

To provide working material for this project, a variety orchard containing over 60 different varieties of peaches was planted at the Truck Station during 1917. These trees have grown so satisfactorily that active work can be done during the following year on this project, favorable weather conditions permitting.

(*c*) *Hardiness of Peach Varieties in Western North Carolina.* Twenty varieties of peaches, comprising varieties adapted both to extreme northern and to southern conditions, were planted at the Mountain Station in the spring to furnish material for work on determining the relative hardiness of different peach varieties in western North Carolina. These trees made a satisfactory growth during the year.

4. *Investigational Work with Pecans* (Truck Station, Coastal Plain Station, and Piedmont Station). (C. D. Matthews and J. M. Dyer.)

(*a*) *Variety Testing.* Twenty-two of the most important southern varieties are included in this test, which has been conducted for nearly 13 years. Gratifying results are being secured from this work, as certain varieties are showing marked adaptability to North Carolina conditions, while others are proving to be undesirable. At this time valuable recommendations regarding pecan varieties for planting in this State can be made. The trees produced the largest crop this year in the history of the orchards. Many trees produced over 50 pounds of nuts.

(*b*) *Securing Individual Tree Performance Records.* The securing of performance records of the individual pecan trees in the experimental orchards at the several stations is being continued from year to year. Such a record affords a more detailed study of the behavior of the different varieties. As a result of the individual tree performance records, it has been noted, that trees of the same variety under identical conditions are uniformly heavy yielders, while others are very poor producers; that some produce uniformly large nuts and others uniformly small nuts. As these individual performance records suggest the possibility of improving and standardizing individual yields by bud selection, work has been started along this line.

(*c*) *Cultural Practices.* The value of correct cultural practices, such as tillage and the use of cover crops, is clearly shown in the increased size of trees and in the increased size and number of nuts produced when compared to trees and their products grown in sod. To determine the most desirable system of tillage and cover cropping to be employed in pecan orchards, work of this nature is being conducted at the branch stations.

(*d*) *Pecan Breeding.* The seedlings secured as a result of pecan breeding work, set in 1915 at the Truck Station, are making a satisfactory growth. Some of these seedlings are of bearing size and should produce some nuts during the coming year.

(*e*) *Top-working Pecan Trees.* The investigations, dealing with the methods of budding and grafting, employed in top-working pecan trees were continued this year. It has been found that a combination of both grafting and budding should be used to secure the most satisfactory results. As a result of years of investigation, it is the opinion of this Division that top-working should be confined, as a general rule, to the trees not over 8 to 10 years old, to be entirely successful.

5. *Investigational Work with Strawberries* (Truck Station). (C. D. Matthews and L. H. Nelson.)

(*a*) *Variety Testing.* The variety-testing project with strawberries was initiated with the purpose of determining whether or not there are any other varieties more desirable as commercial market varieties than Klondike and Missionary, the two leading commercial varieties. For this State the most profitable berry combines the characteristics of productiveness, earliness, and shipping quality. Twenty-three varieties have been tested in comparison with Klondike and Missionary as regards these characteristics. To determine the shipping value of each variety, shipping tests have been made. None of the varieties tested have shown themselves superior to Klondike and Missionary as commercial varieties. Several of the varieties have shown themselves valuable for home use.

(*b*) *Cultural Practices.* During the year experiments to determine the most desirable planting date were started. Work to determine the value of removing blossoms and cutting runners was initiated. This project has not been in operation a sufficient length of time to furnish any conclusive information.

6. *Investigations with Apples* (Mountain Station). (C. D. Matthews and J. M. Dyer.)

(*a*) *Pruning.* The pruning project was begun during the year with the intention of securing information on the desirable height to head apple trees, to determine the comparative value of the open head and the modified leader system of training, and to secure information on the amount of annual pruning most desirable. To supply material for this work an orchard containing approximately 128 trees was planted at the Mountain Station during the spring.

EXPERIMENTAL WORK IN VEGETABLE CULTURE

1. *Investigational Work with Sweet Potatoes* (Truck Station). (C. D. Matthews and L. H. Nelson.)

(*a*) *Variety Testing.* It is the purpose of this work to determine the most desirable varieties of sweet potatoes for eastern North Carolina from the standpoint of productivity, market value, keeping quality, and quality. There were 19 varieties under observation this year. The results were, in the main, confirmatory of the work of previous seasons. Certain varieties have proven their desirability, while others have shown themselves to be undesirable.

(*b*) *Storage.* In connection with the variety work, storage tests are being made from year to year in the storage house to determine the behavior of the different varieties in storage. Certain varieties have proven themselves to be better keepers than others.

Investigations to determine the relation of proper harvesting to keeping quality, the proper method of curing, and the correct management of the house, have been continued this season. As a result of this work, the Division of Horticulture can authoritatively make recommendations regarding varieties for storage and the most desirable methods to employ in the management of the storage house. The work further shows the advisability of employing houses of this type for storage, as the average loss from all varieties has been less than 6 per cent in 1919.

(*c*) *Cultural Practices.* During the year work was done to secure information on the comparative value of the following different cultural practices:

The comparative value of slips vs. vine cuttings as regards productivity.

The effect of ridging on productivity and type of potatoes.

The effect of vine cutting on yield.

(*d*) *Seed Selection.* The following lines of work dealing with the seed selection of sweet potatoes were initiated this year:

To determine the relative value of seed stock from high yielding and low yielding hills (disease-free stock only to be used) as regards:

Productivity

Uniformity of potatoes

To determine the relative value of vine cuttings as compared with the slips for maintaining yield and type, commencing from same hill.

To determine the comparative value of large and small potatoes for seed. Very satisfactory progress was made with this work during the year.

2. *Investigational Work with Irish Potatoes* (Mountain Station and Truck Station). (C. D. Matthews, L. H. Nelson, and S. C. Clapp.)

(*a*) *Variety Testing.* The testing of varieties of Irish potatoes, to determine the most desirable varieties for western North Carolina conditions, was continued this year with 20 varieties. The testing has been

in progress for a sufficient length of time to supply this Division with the necessary information to make reliable recommendations regarding the choice of varieties for the western part of the State.

(*b*) *Hill and Tuber Unit Selection Work.* The hill and tuber unit selection method of variety improvement is being employed in an attempt to produce strains of the best varieties with greater productivity and more desirable characters.

3. *Investigational Work with Cabbage* (Mountain Station). (C. D. Matthews, L. H. Nelson, and S. C. Clapp.)

(*a*) *Variety Testing.* The testing of varieties of cabbage, to determine the most desirable varieties for western North Carolina, was continued this year. The testing has been in progress for a sufficient length of time to supply this Division with the necessary information to make reliable recommendations regarding the choice of varieties for the western part of the State.

(*b*) *Date of Planting.* Work to determine the most satisfactory date for transplanting cabbage was continued during the year.

4. *Observation Garden* (Truck Station). (C. D. Matthews and L. H. Nelson.) The all year observation garden at the Truck Station has proven very valuable in supplying information regarding varieties and planting dates of different vegetables for eastern North Carolina. It has been of value also as a demonstration in gardening, and has been an inspiration to many visitors who have seen it.

Respectfully submitted,

C. D. Matthews,

Acting Chief, Division of Horticulture.

REPORT OF HORTICULTURIST

To the Director:

I have the honor to submit the following report for the year ending June 30, 1919:

The work of research, in connection with muscadine grapes, has progressed during the year without interruption, especial attention having been directed toward the completion of some of the earlier projects as outlined, and the collection of material and prosecution of those of later development. A summary of the six lines of investigation, as they exist at the end of the year, follows:

Project No. 4, "Further Studies of the Inheritance of Sex," is practically complete as outlined, there being but a small amount of data to be secured during the present summer and fall. Report on this work has been made and published at various times, chiefly in Technical Bulletin No. 12, "Inheritance of Sex in Vitis Rotundifolia."

Project No. 5, "Productivity of Rotundifolia Grapes," is practically completed as far as it can be, without the making of systematic vine and variety tests. This work is not recognized as pure research, and, therefore, cannot be carried out at this point. It would, therefore, seem desirable that some of the superior vines grown be tried out on a larger scale than is possible here, and those which possess sufficient merit be introduced to the trade. There are about ten or twelve vines of merit sufficiently great to warrant such observation.

Project No. 6, "Inheritance of Color in Rotundifolia Grapes" is complete as outlined. Report of this work has been made in Technical Bulletin No. 10.

Project No. 7, "Further Studies of the Inheritance of Size of Fruits" is being continued. Partial reports have been made from time to time as warranted.

Project No. 8, "A Study of Quality Characters in Rotundifolia Grapes" is a line of study on which, up to the present time, little work has been done. Some observations as to flavor have been made and reported upon, but others, including disease resistance, are as yet to be worked out.

Project No. 9, "Hybridization of Vitis Rotundifolia with Other Species," is an investigation looking toward the establishment of the limits of hybridization of this species, and the formation of a scale of crossing profitable for use in connection with it. This subject has been the one of especial interest during the year, and although it has been difficult to secure stock of all the species needed, some results have been obtained with the material already on hand. These results have been submitted for publication during the year, and will appear shortly. One of these (Technical Bulletin No. 17) is by way of summary of the work of other investigators, and a report of the results accomplished at this station up to the present time. The other (Technical Bulletin No. 18), deals with the subject of hybrids, both true and false, of which numbers of the latter have found their way into cultivation. The proof of the spurious character of these so-called hybrid varieties serves to clear the way for future work along this line.

New projects have not been instituted as yet, because suitable conditions and necessary time have not been available. It is expected that with a return to more normal conditions, some of these investigations can be carried on.

Respectfully submitted,

J. P. PILLSBURY,
Horticulturist.

REPORT OF THE DIVISION OF PLANT PATHOLOGY AND BACTERIOLOGY

To the Director:

Pursuant of your request, I am herewith submitting a brief report concerning the work of this Division for the fiscal year ending June 30, 1919.

The investigations have been continued, interruptedly, along the several lines mentioned in the previous report, namely, on certain diseases of tobacco and of soybeans. The changes in staff involved by my return on March 1, 1919, and the resignation of Dr. W. H. Tisdale, who was in charge during my absence, together with the lack of assistants, have made impossible the usual progress in the work of investigation. Data of value have been secured, however, and will be incorporated in published accounts of the several diseases. The laboratory studies on the projects have reached the point where access must be had to field tests if adequate proof on methods of control of these diseases is to be secured. It is suggested that this need be met by some project method of support on the Branch Experiment Stations.

Considerable time has furthermore been devoted to a little known vetch disease, which was so generally destructive throughout the State during the spring of 1919, as to practically prevent the formation of seed. The investigations on this disease should be completed during the coming year and prepared for publication.

The only publication of note from this Division during the year has been Technical Bulletin 16 on "Clover Stem Rot." The disease not only attacks crimson clover, but also red clover, white clover, alsike clover, and alfalfa. It may be recognized by a sudden wilting and death of plants in spots, a decay of stems near the surface of the ground, and the presence of black sclerotia in these decaying stems. The causal organism is different from the one causing lettuce drop, with which it has been regarded by some as probably identical. The lettuce drop organism will, however, attack crimson clover, and the stem rot organism will infect lettuce. The disease may be avoided by the use of seed free from sclerotia, by the exercise of care when soil is used to inoculate new fields with nodule forming bacteria, and by not returning manure to clover fields when hay from infested fields is fed. In badly infected fields, cowpeas and soybeans must replace crimson clover as a legume in the rotation system, and winter grains must serve as cover crops.

Respectfully submitted,

Frederick A. Wolf,

Chief, Division of Plant Pathology.

REPORT OF DIVISION OF MARKETS AND RURAL ORGANIZATION IN NORTH CAROLINA

To the Director:

This report is for the year ending December 1, 1919, and covers the investigations, extension, and service work of the Division of Markets and Rural Organization, conducted jointly or separately by the North Carolina Department of Agriculture and the North Carolina State College of Agriculture and Engineering, in coöperation with the United States Department of Agriculture under the agreements and plans entered into by these institutions for the conduct of all agricultural work of this kind in the State.

WAREHOUSE SURVEYS

In 1913 the North Carolina Division of Markets, in coöperation with the Federal Bureau of Markets, made the first survey of cotton warehouse and credit facilities in North Carolina. The counties producing 3,000 or more bales of cotton per year had a storage capacity of 88,875 bales, exclusive of private and mill warehouses. In fact, the first survey of warehouse facilities in the United States was begun in North Carolina. In 1914, when the price of cotton dropped to six cents a pound, another survey made by the Division of Markets showed that an additional warehouse capacity had been developed to meet the emergency of the war amounting to 181,015 bales capacity above what was available to farmers before the war. Of this amount room for 46,100 bales was provided by the cotton mills. This was a time when the farmer had to hold his cotton, or make a great sacrifice. What is more, the merchants and other business interests in the cotton belt could not afford to allow such a sacrifice.

The survey of North Carolina warehouses, made this year, is not complete enough to show the precise capacity of storage houses now available for farmers; but it does indicate, as in 1913, that most of the cotton warehouse space is controlled and used by buyers. Even warehouse companies, which operate public warehouses generally, prefer to store the cotton of buyers, rather than that of the ordinary farmer, as the expense of storage of small amounts is too high to be profitable. The greater rate of cost for storage of farmers' cotton, when it is sold in small lots, should be considered. This extra cost, however, may be met if the Farmers' Warehouse Companies will employ a manager that is capable of acting also as a sales agent for the depositors of cotton. Then the cotton can be sold out in large, even running lots. Our cotton survey has shown that the larger farmer usually obtains a higher price for cotton.

If the farmers were organized to market their cotton in large, even running lots through their own warehouse companies, they would not be selling cotton now at one to four cents below the market, and would

not be losing, in most places, from five to twenty dollars per bale. The State Warehouse Superintendent, in carrying out the provisions of the State Warehouse Act, will be in an excellent position to assist any farmers or merchants who have cotton stored in State warehouses to market their cotton, as the law requires that the superintendent keep a record of the grade, staple, and weight of all cotton stored in the State system. To efficiently carry out the provisions of the law to assist depositors of cotton to market their cotton, it will be necessary for this Division to make its present weekly price report a daily report for cotton. This will be necessary for the information of the superintendent and of the depositors of cotton. The State Warehouse Act requires that all cotton stored in a State warehouse be graded. This can be done by our State graders or by graders licensed under the North Carolina standard grading law, or under the United States Warehouse Act. On the other hand, if the warehouse company acts as a marketing agency for its depositors it will make our grading service more effective, as it has been found that buyers generally will not buy cotton on the basis of State grades unless the seller is in a position to find other markets where the cotton may be sold on the basis of such grades. Thus, the State Warehouse System, to be effective, has to be combined with the organization work, cotton grading, market news service, and sales work of the State and Federal Bureaus of Markets. Such a complete system will have all the necessary elements of success in it for the operation of the State and Federal Warehouse System.

GRAIN AND SOYBEANS

Surveys have been made of roller mills to find out the demand for corn. Last year North Carolina mills were in the market for a considerable amount of North Carolina corn, but this year improvement of transportation, and decreased demand for corn as a substitute for flour, has made the mills less interested in home grown corn. Lists of interested mills and buyers have been furnished to growers and shippers of corn. The great difficulty of farmers shipping their own products has been lack of warehouse space. The Hyde County Grain Exchange, organized by this Division, may be said to have failed largely because of lack of a warehouse for assembling corn, soybeans, and oats. This county, alone, loses approximately $25,000 yearly for lack of proper marketing facilities.

Wholesale receivers do not care to buy direct from farmers who are not prepared to make immediate delivery in the quantity wanted. The proposed warehouses at Elizabeth City and New Bern, together with the one already existing at Washington, would enable many of the farmers of our corn belt to store corn for spring and summer sale when local corn has been sold, and when only prices are as high as, or higher, than the price of western corn delivered in this State. A warehouse

company, with an efficient sales manager, can guarantee quality of grain and develop a reputation for business methods.

A survey of the market for soybeans has also been made, through letters addressed to seed houses and to marketing agents in other States. Prices producers secured for soybeans have been found to be $1.50 to $2 per bushel as compared with $3 to $4 last year. After the farmers had sold practically all of their soybeans, the price rose to $3 per bushel, or better. The opinion is held that if growers had been organized to store their soybeans and to market them when the trade had sold out its holdings of last year's stock, growers would have been able to receive three dollars a bushel for their crop. One or more county agents have had trouble with receiving seed that would not germinate. The remedy seems to be for farmers to organize warehouse companies in accordance with the warehouse and coöperative laws of North Carolina, put their soybeans in storage, clean, and grade them under the provisions of the North Carolina Standard Grading Law, borrow money, if need be, on their warehouse receipts, and be ready to sell in large, even running car lots direct to wholesale seed houses, or to farmers' clubs through State marketing officials and county agents, when prices are satisfactory.

PEANUTS

A survey in person was made of the market for peanuts in Suffolk, Norfolk, New York, and Philadelphia, and by letter or wire of Pacific Coast and Southern markets. Very soon after the Armistice was signed, Virginia peanuts dropped in price to the producers from nine cents a pound to four and five, a decline that has no parallel in any other food product. Farmers were unable to sell more than a few peanuts at any price. The trade had a considerable hold over from last year, and after the demoralization in prices, was only willing to buy from "hand to mouth." The cleaners appeared to fear that the removal of the embargo upon foreign peanuts by the War Industries Board would cause all American markets to be flooded with low price nuts. As prices quickly recovered, the removal of the embargo proved to have only a temporary effect. Cleaners claimed that maintenance of war prices to producers would not permit of consumption of the larger crop assumed, but admitted street venders were selling peanuts to consumers at war prices, and making from $15 to $25 per bag profit. Farmers are estimated to have sold peanuts with little profit, and in most cases with some loss, the loss ranging, in some cases, as high as $25 per acre. One of the leading manufacturers of peanut butter, candy, and salted peanuts was of the opinion that conditions would have been greatly improved if cleaners had carried on an advertising campaign to dispose of peanuts through the retail grocer as soon as the War Industry Board declared peanut marketing by street venders as a nonessential industry. In May and June, after farmers disposed of the most of their crop, prices recovered

a large part of the slump, rising to seven and eight and one-half cents a pound for Virginia nuts. Circulars, based upon these investigations which we issued, helped to give farmers confidence at a time of general business demoralization. Most farmers have no suitable storage facilities for holding peanuts. Besides, a large part of the crop is owned by tenants or small farmers who are obliged to sell at some price. For any plan of organization to be effective, the membership would need to control a large part of the crop. Provisions would have to be made for financing the holding of the "distressed" peanuts, proper storage facilities built, and arrangements made for the Growers' Exchange to enter into a collective bargain with the cleaners. A collective bargain, as worked out by the California Prune and Strawberry Growers, and by milk producers in other States, must include in the contract detailed provisions as to grades, rate of sale, and price. The program of the Virginia-Carolina Peanut Exchange does not seem to meet these minimum requirements. The warehouse companies being organized in the peanut belt are making plans to solve these problems.

SWEET POTATOES

A survey was made of sweet potato storage houses, variety, place of disposal, and prices received. This information showed that the demand during past year for sweet potatoes in storage houses was generally sufficient in local markets. In a few places, southern late sweet potatoes are shipped North, but the most of the crop is sold, either on local markets, or nearby markets in the State. In any event, prices have generally been so good this year, ranging from $1.50 to $2 per bushel, that little selling assistance has been necessary.

MOUNTAIN PRODUCTS

In the western counties of the State investigations have been carried on in varieties, culture, harvesting, grading, packing, and storing and marketing fruits and vegetables; especially apples and Irish potatoes. These investigations have shown the need of a few standard varieties adapted to this section, properly grown, harvested, graded, packed, stored, and marketed. One thing needing special emphasis in culture of both apples and potatoes is spraying. This need has been realized in the case of apples, and is coming to be realized in the case of potatoes. Marketing investigations have revealed in the case of potatoes, with an occasional rare exception, that late summer and early fall are the best times for farmers in western North Carolina to sell their Irish potatoes. The western North Carolina potatoes can be dug and put on the southern markets before the big eastern, northern, and western crops can reach these markets, at a time when the eastern shore and southern Irish potatoes have been cleaned up and the demand for potatoes is good. Only in years when the potato crop over the whole country is below

normal has it paid western North Carolina farmers to hold their Irish potatoes until winter or spring.

HOGS

A careful survey of the fat hog marketing situation showed that the prices obtained on local markets last fall and winter were, in most cases, relatively higher than packer markets. This was especially true with soft hogs, as local markets almost invariably paid as much for soft hogs as for hard hogs, while packer markets deducted from 2 to 4½ cents per pound for soft hogs. However, about February local prices began to drop, and by March were considerably lower than packer markets. This condition was favorable for encouraging and making coöperative car lot shipments to packer markets. Eighteen such shipments were made. In the past North Carolina hogs have been sold locally, a greater part of them going on the market as dressed hogs and as cured meat. However, with the adoption of the coöperative plan of selling, it is thought that selling on foot will rapidly grow in favor. The coöperative marketing of hogs is being urged where local markets are out of line with packer markets. The determination of whether hogs are hard or soft by packers has caused dissatisfaction and discouragement among farmers who have taken pains to harden their stock. It now seems evident that it will be necessary to have a disinterested party stationed at packing centers to determine whether hogs are killed hard or soft. It is thought that if such an arrangement can be made, many more North Carolina farmers will harden their hogs before marketing them.

BEEF CATTLE

The method of marketing feeder, stocker and butcher cattle in the western part of the State is being given considerable study. A large per cent of these cattle are sold by growers to dealers, who contract for them anywhere from one to six months prior to date of delivery. The prices obtained by growers are usually considerably below the actual value of the cattle. Growers are being encouraged to ship their butcher cattle to packer markets, rather than sell to local dealers, and some growers have shipped cattle this year, for the first time, with satisfactory results. During the past fall considerable assistance has been given in selling feeder cattle by bringing grower and feeder together, and several sales have been made in this way. However, this plan is only fairly satisfactory. Plans are now under way for holding two big feeder, stocker, and butcher cattle sales at two different points in the western part of the State during the fall of 1920. It is thought that this plan of selling these mountain cattle will be more satisfactory to the grower than the old plan, and at the same time encourage the raising of more cattle. Coöperative shipping of grass fat butcher cattle to packer markets is being encouraged, and a few such shipments have been made this year.

As a rule, heavy cattle command the best price on packer markets. Cattle feeders frequently object to North Carolina feeder cattle, on the grounds that they are not large enough when put in the feed lot to command the highest prices when finished. This fault could be overcome if the cattle raisers would keep their cattle a year longer before selling to cattle feeders.

The plan of marketing fat cattle in the central and eastern part of the State has also been investigated. A large per cent are sold to dealers who travel over the State. The feeders seem to prefer this plan of marketing, rather than shipping them to packer markets to be sold through commission men. When cattle feeders have a carload of cattle, and are posted as to the cattle market, they usually obtain a fair price for their cattle from these dealers. However, when a cattle feeder has only a few cattle for sale, or is not posted as to markets, it is quite likely that he will sell his cattle considerably under actual value. This office is encouraging cattle feeders to ship their fat cattle to packing centers, rather than sell them to traveling dealers.

It has been found that a large per cent of the cattle fattened in the State are sold before sufficiently fat to command the highest price at market. This is due largely to the fact that insufficient concentrates are fed, rather than to the length of the feeding period.

SHEEP AND WOOL

While there are relatively large numbers of sheep in the eastern counties of the State, very little attention has been given to marketing them. They are raised in small farm flocks, and farmers have been taking whatever they could get for them. Prices have not been such as to encourage improved breeding; consequently, the quality is somewhat inferior. Practically all sheep have been sold to local markets and consumed within the State. The coöperative shipments to northern markets, during the past few months, have caused the farmers to understand they can get full market value for their lambs and sheep, and new interest is being aroused in the industry. One great need, if they are to secure the best prices on northern markets, is improved breeding and care.

Western and Central North Carolina farmers grow sheep in larger flocks, give more attention to breed and care of flocks, have better marketing facilities, and obtain better prices. In this section many good local markets are available, and in some cases dealers buy and ship to northern markets. While this situation is far from ideal, it is much better than in eastern North Carolina, where buyers make purchases in small lots and operate on a larger margin of profit. The shipping of lambs to northern markets, from the extreme western counties of the State, is not so satisfactory as from the eastern counties, on account of distance and poor shipping facilities which cause more or less loss

en route. However, after arrival at market they command a higher price than eastern North Carolina lambs, due largely to improved breeding.

During the summer of 1919, six coöperative car lot shipments of lambs were sent to northern markets with very satisfactory results. In one case, the net price received was double the price offered locally. This plan of marketing will be pushed during the coming year.

The quality of wool produced in central and western North Carolina is good. A large per cent of it is sold to traveling buyers, who usually pay only one price for wool of a particular section, regardless of quality. The payment, by buyers, of a flat price for wool, as for cotton and other farm products, does not encourage the production of the best quality. The price obtained for this wool has always been low enough to allow the buyer a big profit. In the eastern counties a poorer grade of wool is produced. The plan of marketing this wool is the same as in the western part of the State, but it usually sells for considerably less. Taking the State as a whole, there is a decided need for a better plan of marketing both wool and lambs. On the other hand, there is need for improved blood in the flocks, and better care and feed is needed in many cases.

During the past summer several coöperative sales of wool were made. In some cases the wool in a county was collected and held in storage until a satisfactory bid was made. In other cases small coöperative shipments were made direct to woollen mills. On August 20th wool from eight counties in the State was collected and shipped under the supervision of county agents to the Philadelphia market, where it was assembled, graded, and stored, and later sold. This plan of selling wool is only fairly satisfactory. It is thought a better plan would be to assemble and store it in three or four convenient places in the State, and later offer it at auction. Plans are now under way for holding at least two such sales next year.

THE ORGANIZATION OF THE STATE WAREHOUSE SYSTEM

Since early in September, when the present State Warehouse Superintendent was appointed, the warehouse regulations have been revised and printed; a form of North Carolina and United States negotiable warehouse receipt, together with coupons, has been drafted and printed; forms for nonnegotiable memorandum receipts and warehouse licenses have been drafted and printed; and a form of bond for bonding local warehousemen has been drafted and approved by the Assistant Attorney-General. The nonnegotiable warehouse receipt is to be given by the local manager of a warehouse to the depositor of cotton, and later is to be exchanged for a negotiable warehouse receipt when the cotton stored has been insured, weighed, and graded. The main changes in the revised regulations, as approved by the Warehouse Committee of the State

Board of Agriculture, are (1) to make the local manager responsible for the enforcement of the regulations under the United States Warehouse Act, as well as of those under the North Carolina Warehouse Act, and (2) to reduce the privilege fees charged warehousemen from five cents to one, three or five cents per bale per month. The amount of charge varies according to the saving on insurance to the warehouse. The previous flat charge of five cents per bale per month was prohibitive. The bond of $100,000 required under the State Warehouse Act has been arranged for the State Warehouse Superintendent with much difficulty, due to the present wording of the Warehouse Act.

According to section 17 of the Warehouse Act, the State Warehouse Superintendent is required to insure and keep insured all cotton stored in State warehouses. The present State Warehouse Superintendent has invited all general agents, brokers, and representatives of the local insurance agents to submit proposals which would meet the requirements of the law. To date only one agency has offered any such plan. The plan offered by this agency has been accepted, subject to the final approval of the State Board of Agriculture, and also subject to the condition that it remains the best plan offered. By this plan all warehouses brought under the State warehouse system, which have as good a system of inspection as that of the Federal, will obtain a twenty-five per cent reduction on existing insurance rates, provided they are nonsprinkler warehouses, and ten per cent reduction if they have a sprinkler system. It is further agreed that a floater policy of $300,000 will be issued to cover each warehouse, which will protect the State from any loss on account of any carelessness, up to the amount of $300,000. The records of this office are accepted as legal evidence of the cotton insured up to this amount. Any amount, either in excess of or under $300,000, may be taken out as a specific insurance with any company acceptable to the warehouse owners and to the State Warehouse Superintendent and Insurance Commissioner. If any other agency should offer a better plan, the floater policy should be required, and the other essential principles of this arrangement should be held to as fundamental for the protection of the State against loss. With the arrangement of this tentative agreement by the present State Warehouse Superintendent, the State warehouse system was made ready to operate on October 29th.

The warehouses of the State have been canvassed by letter once before the first of September, and twice since, to invite them to come into the State and Federal Warehouse System. Since the first of September, copies of Warehouse Bulletin, revised regulations, license blank, and of warehouse receipt have been mailed to each of the three hundred and thirty-six names we have on our warehouse mailing list. In addition, the beginning has been made by a personal canvass of all the principal warehouses in the State, which should be continued until completed, in order to give an opportunity for each warehouseman to ask questions and to

have them answered. This canvass will also serve to obtain a complete list of warehouses now active or available. Two applications for license have been received and one approved.

The mill warehouses, now, do not need the credit of the State to increase the value of their warehouse receipt as collateral for borrowing purposes. When the ever-recurring periods of money stringency come again, many of the mill owners may be glad of the support of the credit of the State to increase the borrowing power of their warehouse receipts. The same will be true of the buyers' warehouses, which constitute almost all the other warehouses of the State. Most of the farmers' warehouses, which once were scattered over the State, have passed into other hands.

No special appropriation was allowed for this warehouse work by the board, and, therefore, it has not been possible to employ additional assistants. The warehouse work will need to be made as strictly an educational project as any other line of work conducted by the agricultural institutions of the State. There is no more reason why the warehouse project should be made to pay its own way than any other line of production or marketing work. Warehousemen are not going to come under the State and Federal system until they understand fully the requirements of the warehouse acts and regulations, and the advantages of operating a warehouse under this system.

PROMOTION AND ASSISTANCE IN THE MAINTENANCE OF WAREHOUSE AND MARKETING ORGANIZATIONS

Organization of Warehouse Companies to Operate Under State and Federal Warehouse System

The low price of cotton last spring and summer, and the losses suffered from holding cotton out-of-doors, has made this a favorable year for the organization of warehouse companies for operation in the State and Federal Warehouse System. Farmers, generally, have shown an interest in organizing warehouse companies under the coöperative and warehouse acts of North Carolina. Then the field is comparatively clear for starting such projects, as most all of the farmers' warehouses have gone out of existence, and most of those warehouses in existence are under the control of cotton buyers or mill owners. However, the tenth of September, when the present State Warehouse Superintendent was appointed, was a rather late date for promoting warehouse companies this year.

A plan of organization of a warehouse company was worked out in connection with the Chowan Coöperative Warehouse Company, which the present Acting State Superintendent of Warehouses promoted, in coöperation with the county agents of Hertford and Bertie counties. By-laws and a form of stock subscription blank were furnished this organization. The company plans to operate a chain of warehouses

under one manager, and to store and market cotton and peanuts. The farmers in these two counties have not pushed the sale of sufficient stock to build the three warehouses planned, as it has been decided that the present high prices do not warrant the holding of cotton.

Though this may not be a good time for holding cotton, it is highly important that farmers, bankers, and merchants use the present time of prosperity and surplus funds to organize a warehouse company, and to subscribe sufficient capital which can be utilized for building warehouses another summer when material may be bought at lower prices. If, however, the capital is not collected now, the present surplus of money may be spent and, therefore, would not be available for warehouse construction in time for meeting the great need for warehouses in the future.

A plan for a chain of warehouses has been adopted and carried out by the Northampton Warehouse Company, which has thirty-four thousand dollars subscribed toward building three warehouses at Seaboard, Jackson, and Rich Square. Two of these warehouses will be built at once. This company also plans to market, as well as store, both cotton and peanuts, and to secure a competent manager for this purpose. Competent managers will need to possess ability to act as sales agents, as well as warehouse managers. Farmers seem to be willing to pay a guaranteed minimum salary of $1,500 to $2,400, with a percentage of net profits to be given as a bonus, which together should make a salary of $2,500 to $4,000 per year. At least one other such warehouse company should be organized in the peanut belt, in order to construct and operate warehouses in Washington and Martin counties. A banker and the county agent at Plymouth are ready to proceed as soon as the services of an organizer can be secured. A company, with a paid in capital stock of $5,000, has been formed to build a warehouse at Conetoe. However, this warehouse company had best be made a part of the company which will be organized at Plymouth.

Larger concentration warehouses should be built at New Bern and Elizabeth City to store cotton, corn, soybeans, and any other products which are brought from nearby or distant sections for disposal on these markets. Washington, with similar conditions, has a storage warehouse with a capacity of 6,000 bales, which shows what a warehouse can accomplish. It is one of the very few purely public warehouses in the State. This warehouse stores cotton, corn, soybeans, and other products of commerce. It has a very low insurance rate of 20 cents per hundred. Automobile dealers find it profitable to store machines in this warehouse, because of the saving in insurance. Some plan should be worked out to enlist the farmers of Hyde County to take an interest in this warehouse, as undoubtedly they will if this warehouse company obtains an efficient sales manager, and if a canvass is made to show them the advantages of assembling their products in a warehouse. However, all warehouses,

especially those located in the territory tributary to Norfolk, to serve their depositors must have efficient sales managers. To find efficient sales and warehouse managers, with ability to keep track of markets for such diverse products as cotton, peanuts, soybeans and corn, will be one of the most difficult tasks. Upon the solution of this problem will depend the development of an efficient marketing system for handling the farm products of the whole northeastern North Carolina.

The companies which are being organized in northeastern North Carolina will look to the State Warehouse Superintendent to fully carry out the provision of the law which gives him the authority to market the cotton stored in all warehouses upon the application of the owners. Warehouse companies, to build warehouses and operate them under the State system, are also being formed at Greenville, Warsaw, Clinton, Fayetteville, Angier, and Monroe. Eight warehouse companies, being thus promoted, have a subscribed capital of approximately $160,000. There are good prospects for warehouses at Smithfield, Dunn, Lumberton, and Rowland. If possible, the warehouses to be built at Clinton, Warsaw, Burgaw, and possibly Faison, should be operated as a chain of warehouses by one company under one first-class manager, with assistant managers for each warehouse.

Such cities as Fayetteville, Raleigh, Goldsboro, Wilson, and possibly Wilmington, should become great concentration points according to a plan similar to that adopted at Spartanburg, South Carolina. At Spartanburg auto trucks bring in cotton from thirty miles around at a cheaper rate than freight. However, the auto truck in localities where production is more scattering, might not be feasible. If the railroads will extend the storage-in-transit privilege to all these cities, successful operation of large warehouses in them will be assured.

The North Carolina Warehouse Law is so drastic and complete in its provisions for safeguarding the warehouse receipt that bankers usually have shown a positive interest in our warehouse organization work, and should be expected to lend every effort to coöperate with farmers and business men to build warehouses. The State and Federal warehouse receipt will furnish the bankers the very best security with which to secure funds in time of money stringency.

If, however, farmers do not proceed at once, buyers will erect warehouses of their own and preëmpt the field. For the farmers to control their own warehouses, so that they can store when the need is greatest, the State Department will need to provide the necessary funds for the Division of Markets to have one organizer in the field full time for the next six months to a year. This will assure such understanding of the coöperative and warehouse acts in the promotion of the warehouse companies as to conserve the farmers' interest, and to assure that all companies promoted will come into the State and Federal system as soon as formed.

Any farmers' warehouse company, which is not formed under co-operative law, is likely sooner or later to pass out of their hands. This is another important reason why some one should be appointed as organizer, so as to instruct the farmers in the advantages of coöperative law. The coöperative law gives farmers authority to restrict membership to those agreed in their purpose, to limit voting power to one vote to each member, to limit dividends to six per cent, and to prorate surplus profits to depositors of cotton and other products in proportion to the amount stored. This prorating of surplus profits will give depositors a reduced storage rate at cost, and thus encourage a maximum use of the warehouses by farmers.

According to investigations made by the Bureau of Markets in this and other States, cotton on an average is damaged by weather exposure two dollars and a half per bale. If this amount were saved each year, it alone would build the warehouses for the State warehouse system. If each farmer in North Carolina would invest at the rate of three dollars per bale, this, with the help of business men, would build most of the warehouses needed in the cotton producing counties. Thus, the saving from weather damage would pay every farmer to own stock on the basis above specified as a part of the necessary equipment of his farm; in fact, quite as necessary to a cotton farmer as a barn for storage of farm machinery and feed.

It will be a great help to make the warehouse company pay expenses including dividend, and a fund to cover depreciation of building, if arrangements are made in each county to have the official weigher of the warehouses appointed by the county commissioners as an official weigher for the county.

As soon as a half dozen warehouses are in operation under the State warehouse system, weekly and monthly reports should be issued for warehouses similar to those now issued for the credit unions. These reports should be sent to all shareholders of warehouse companies, or to owners of warehouses, and to North Carolina mill owners and to any interested mill owner outside of the State. This will maintain the interest of the shareholders, and draw the attention of the mill owners to the kind of cotton available in North Carolina warehouses. Statements should indicate cotton received each week and delivered, and amount on hand of each grade and staple.

PROMOTION AND MAINTENANCE OF MARKETING ASSOCIATIONS

A new organization, known as the Eastern Carolina Produce Exchange, with central office at Aurora and branch offices at Washington and Pantego, has been promoted by this office for marketing Irish potatoes. The membership of this organization is already sixty-one, and the acreage, which was contracted to be handled through the exchange, amounted to six hundred and thirty. This exchange marketed

150 cars of potatoes during June, 1919, with an estimated saving to the growers of from $15,000 to $25,000. The average net price, received by growers from 21,889 barrels of grade one, was $4.70 per barrel, and for 3,778 barrels of grade two $2.50 per barrel, or an average net price of $4.45 per barrel for all grades. This exchange designed and adopted an excellent brand, and had the brand and grade printed on its cloth top barrel covers, which added greatly to the selling value of its potatoes. This division licensed the four inspectors of the Exchange, and furnished the service of a supervising inspector, so that the Exchange had authority to, and did issue certificates of grade according to the provisions of the Standard Package and Grading Law. With the Carolina Potato Exchange at Elizabeth City, and the new exchange, there will be organizations in all leading early Irish potato producing sections, except the Mt. Olive section, where several unsuccessful attempts have been made to organize.

The Carolina Potato Exchange, which was organized by this Division in the year 1914, marketed for its members this year 169 cars of Irish and sweet potatoes. The 42 cars of Irish potatoes netted the growers $4.46½ per barrel. The 7,258 barrels number ones netted $4.52 per barrel, and the 212 barrels of number twos brought the growers $2.36 per barrel. The 21,572 barrels of Big Stem Jersey Sweet Potatoes, grade one, brought the growers $4.77 per barrel, and the 577 barrels of grade two $2.56 per barrel.

An assistant manager was furnished to the Tabor Produce Exchange this year, who assisted the Exchange to market twenty-five cars of strawberries. One cold storage and marketing association for handling apples, potatoes, and cabbage in the mountains, two peanut and cotton warehouses, and one strawberry association in eastern North Carolina are being promoted. A representative of this Division acted as manager for the Mountain Growers' Exchange, and, from the branch office located at Waynesville, looked after the marketing of perishable products grown in the mountains. Six cars of late Irish potatoes, United States grade one, sold early in August, netted the members of the Exchange $1.83 3/5 per bushel. The potatoes sold in October brought the members $1.53 per bulk bushel.

Representatives of the Division of Markets, and of the Federal Bureau of Markets, coöperated with the members of the Edgecombe Cotton Exchange to secure a reorganization of the association. The Exchange entered into a contract with members, which was enforced by a note to cover damages for nonfulfillment, to market about 1,500 bales of cotton for the members. This cotton was stored in a warehouse to await the rise of prices.

Growers have been assisted in marketing 18 cars of hogs, and 6 cars of lambs coöperatively, and in selling approximately 12 cars of cattle. Plans are under way for organizing 4 coöperative livestock marketing associations. In most cases, they have resulted in a considerable saving

to shippers. One car lot shipment resulted in a saving of $591.39 over price offered locally.

ORGANIZATION, INCORPORATION, AND SUPERVISION OF CREDIT UNIONS

Twelve new credit unions have been organized, and three old credit unions given a new start. The resources of the North Carolina credit unions have increased from $25,325.98 in 1918, to $53,437.07 on September 30, 1919. Less money is borrowed from the banks, and more obtained from shareholders and depositors. The credit unions of this State have doubled in resources each year from the beginning of the work. If this rate of growth continues, their resources in five years will amount to $1,600,000. Wherever a community possesses leadership and experience in coöperation, credit unions are easy to organize and maintain. The difficulty is the general absence of disinterested leadership in the country community.

It has been proven in North Carolina, as in European countries, that credit unions are of assistance to the banks which are selected as depositories in bringing savings to them. The Bahama Credit Union increased its deposits about eight thousand dollars in four to six months. This credit union is in a county of the State in which the bankers had carried on a campaign to obtain deposits. It was found that 40 per cent of the depositors of the Bahama Credit Union had not been doing business with any bank before. The bank pays the credit union 4 per cent, and the latter agency pays members or nonmembers four per cent for deposits. The credit union pays its own expense out of the profit on the loans it makes to its members for which it charges six per cent.

The credit unions in this State grant their main loans to assist their members to make coöperative cash wholesale purchase of fertilizers. This is evident from the following very excellent report which was made by the treasurer of the Carmel Credit Union.

LOANS MADE BY THE CARMEL CREDIT UNION AND SAVINGS MADE BY MEMBERS THROUGH COOPERATIVE PURCHASE OF SUPPLIES FROM JANUARY 1, 1919, TO JUNE 1, 1919

Money Borrowed	*Amount Borrowed*	*Estimated Time Price and Interest*	*Amt. of Saving Through Cash Purchase*
For fertilizer	$2,360.00	$2,714.00	$354.00
For mules	150.00	165.00	15.00
For food and feedstuff	350.00	385.00	35.00
For labor	265.00	265.00	.....
For farm machinery	115.00	126.00	11.00
For cows	500.00	550.00	50.00
For milk trucks	500.00	600.00	100.00
For holding cotton	560.00	760.00	200.00
For digging well	100.00	110.00	10.00
For repairing barn	75.00	82.50	7.50
To secure farm loan	300.00	322.00	22.00
	$5,275.00	$6,080.00	$805.00

Time of loan: 60 days to 12 months.
Number borrowers, 22; saving to each borrower, average $36.59.
Number notes made, 32; average loan, $165.

Bought 60 bus. soja beans { $165. Individual purchase price cost.
117. Coöperative purchase price cost.
$ 48. Saving.

Enabled 20 bales cotton to be held for 2 cents lb. better price. Saving, $200.

The interest in our credit unions is widespread. We have coöperated with persons throughout the United States who are interested in promoting coöperative credit legislation, and organization of credit unions among farmers and wage earners.

The progress of our credit union must be slow until farmers realize the necessity to organize for coöperative credit, in order to be free to buy where they can buy cheapest, and free to sell where they can sell to advantage. Farmers who are dependent upon the supply store form of credit are not free to coöperate to market their products through organizations controlled by themselves. This has already been proven true of cotton, peanuts, and potatoes in this State. The credit unions, in providing credit for farmers at a more reasonable rate than supply merchants, are not making their profit from the sale of farm supplies, and, therefore, have no interest in restricting diversification in agriculture. A *progressive agriculture* cannot be expected among farmers unless they are in control of their own system of credit and are free to grow what they choose. Farmers have the alternative of wasting their surplus in expenditure for luxuries, or in building up a supply of credit under their own control, which they can use in hard times when the need for credit extension is general and when bankers never have sufficient money to meet the needs of the rural community at large, when, in fact, the bankers say they can only look after their regular customers. The war has given the farmers a surplus. If they do not use it to build up their own credit organizations, they may have to again bear the burden and expense of the old supply store system.

During the war, rising prices have greatly increased the profits of farming, as of other industries. But, as soon as falling prices set in, costs will be high, for the production of farm products, margin of profits will be small or disappear entirely, and advances, or some form of credit, will again be needed in greatly increased amounts in order to run the farm from one crop sale to the next. In the next few years, therefore, the organization of credit unions will be much more urgent and rapid in this State, for the ground has been broken and the favorable attitude of mind on the part of the farmers slowly created, so that they are beginning to realize as never before the value of their own community system of credit.

The last financial statement of the North Carolina Credit Unions is as follows:

MONTHLY FINANCIAL STATEMENT OF NORTH CAROLINA CREDIT UNIONS AS ON SEPTEMBER 30, 1919

Name	Date Opened	Members	Depositors	Payment on Shares	Deposits	Loans	Borrowers	Borrowed from Banks	Cash in Banks	Total Resources
Valdese	Feb. 10, 1917	83	105	$ 2,350.00	$13,702.41	$15,263.73	23	$	$ 1,291.46	$ 16,999.55
*Bahama	April 14, 1916	45	73	570.25	8,545.11	7,775.00			441.45	12,869.48
Carmel	Jan. 26, 1916	113	39	2,039.50	1,636.05	5,260.00	25	1,550.00	219.74	5,593.42
*Sharon	Feb. 10, 1916	73	62	791.85	1,862.19	3,400.00	17	850.00	328.98	3,747.92
Lowes Grove	Jan. 20, 1916	56		1,012.50	837.78	2,970.94	20	1,050.00	42.84	3,112.50
Mount Ulla	Jan. 29, 1918	67	11	590.00	246.90	2,555.22	10	1,638.72	21.37	2,633.51
*Piedmont	April 19, 1918	75	2	867.28	169.75	1,092.33	10	100.00	119.06	1,219.99
Drowning Creek	Mar. 16, 1916	33	5	352.14	45.95	999.48	7	700.00	110.85	1,146.73
Oakdale	Feb. 16, 1916	27	1	218.50	113.58	700.00	10	605.00	185.48	997.84
Eureka	Mar. 17, 1916	30	3	488.75	204.82	388.68	3		309.59	703.09
*Sadler	Mar. 14, 1918	38	3	510.00	175.00	450.00	3		228.30	699.95
Wendell		36	12	86.00	359.22				452.66	582.72
*Angier	Dec. 20, 1918	35	1	454.00	100.00	500.00	1		65.50	565.50
Laurel	Mar. 10, 1917	42	6	510.75	15.50	75.00	1		81.48	554.03
*Lakeview	Jan. 20, 1918	8	3	230.00	7.50				238.25	238.25
Juniper Level		25		194.50					205.75	205.75
*Mount Vernon	Sept. 10, 1917	13	3	100.00	71.64	20.81	1		154.42	188.88
Dundarrach	Feb. 21, 1919	14		85.00		158.75	2	100.00	29.25	188.00
Springfield	July 11, 1919	28		161.25						161.25
*Rosin Hill	Feb. 15, 1919	20		145.00		80.00	1		70.00	150.00
*Franklin	April 6, 1919	19		120.15					119.50	125.75
Jeffries	July 12, 1919	29	8	109.25					116.50	123.00
Warren Plains	June 14, 1919	11		110.00						110.00
*Cleveland	Mar. 29, 1919	18		78.00		51.00	1		24.21	82.71
Arcola		16		67.57					71.50	71.50
*Gold Hill	April 5, 1919	15		62.50					58.75	65.50
Shotwell	July 11, 1919	24		51.50					57.00	57.75
Total Sept. 30, 1919		1,008	337	12,393.21	28,093.42	41,740.94	135	6,593.72	5,086.39	53,437.07
Total Sept. 30, 1918		655	282	7,531.52	11,940.28	21,919.82	161	4,551.40	1,924.96	25,325.98

*According to last report.

The work in credit, however, cannot be measured by any financial statement, however accurate and complete. Much good comes whether or not organization is affected in encouraging farmers to a wiser use of credit. Many farmers do not have the investment point of view, especially in the South, where the ideals of a leisure class have been more prevalent, and where, in consequence, an honorable expenditure of money for consumption may interfere with saving or borrowing capital for money making. The policy has been to show farmers the high cost of supply store credit, and that borrowing is not a misfortune when the rate of interest is low enough and the investment is in an improved equipment or for adequate supplies which permit of a higher rate of return than the rate on the borrowed capital. Undoubtedly, as the agricultural clubs or community organizations get fully established, which are spreading throughout the United States, the credit union will be found a most valuable asset to the farming community in financing the program for the adoption of improved methods of farming advocated by these clubs.

When the individualistic point of view is abandoned by the agricultural institutions, by the schools, churches and by the country community as a whole, the credit unions no longer need work in isolation. Farmers will feel that their only salvation in dealing with vast aggregations of capital is through organization. The credit union is only one of the organizations needed for the development of the rural community. As soon as the closely related organizations, such as organizations for agricultural and social improvement, coöperative selling and buying association, which may or may not be local, are developed, then the suspicion which characterizes the present position of the farmers will be replaced with confidence and efficient teamwork.

No community organization for credit can solve the problem of short-time credit for farmers unless the system provides for regional banks which *shall* discount the notes of the local credit union. At present the credit union is dependent upon the local bank. But the local bank is generally helpless to meet the enlarged needs for credit extension which occurs at a time of falling prices and of sectional or general industrial depression.

CLASSING COTTON FOR FARMERS AND MILLS

Offices have been established at Tarboro, Wilson, Clinton, Fayetteville, Lumberton and Raleigh for the purpose of serving promptly the farmers of Edgecombe, Wilson, Sampson, Cumberland and Robeson counties. Arrangements were made with all ginners in these counties to send samples of each bale of cotton ginned by them to the nearest office, which samples were identified by numbers corresponding to those upon the bales themselves. Upon their receipt, the samples were classed and the owner of the bale from which the sample was taken was notified of the grade and staple of his cotton and its approximate value, as compared

with the quoted price of middling. The data secured in this and previous investigations indicate that farmers received about one dollar for every cent expended in rendering this service. Twenty-six thousand and eighty-one bales have been classed for farmers in this manner during the present season, and about 4,036 bales were classed for cotton mills.

ESTABLISHMENT OF GRADES AND INSPECTION SERVICE FOR POTATOES

The new Standard Grading and Package Law gives the State Department of Agriculture authority to establish grades and regulations for grading, marking, branding and inspection of all farm products. In conformity to this statute, the Chief of the Division, upon the approval of the Director, issued the grades recommended by the U. S. Department of Agriculture on May 1st, which became the legal grades for North Carolina on June 2, 1919, that is, after thirty days notice required by law. Regulations to cover the grading, marking, branding and inspection of Irish potatoes were promulgated, which became effective on June 7th. Three thousand copies of grades and regulations were mailed and distributed to growers and shippers. The State was divided into four districts and a supervising inspector appointed for each district. The duties of supervising inspectors were (1) to interpret the grades to growers and shippers as far as may be feasible, (2) to see that licensed inspectors inspect according to law and regulations, and (3) to see that there has been a proper compliance with the law for maintaining the standard grades for North Carolina.

One or more inspectors were licensed for each of the leading loading points, who had authority to issue certificates of grade upon application. Five inspectors were licensed for potato exchanges and thirteen for the general public. One hundred and sixty cars of exchange potatoes were inspected and 209 cars for individual growers and shippers. Buyers on three markets coöperated to the extent of requiring that all potatoes be graded and inspected. If potatoes did not come up to grade, these buyers would require growers to run potatoes through a grading machine located at the loading point. It is hoped that this plan may be extended to several other markets the coming year. According to reports received, the grading of early Irish potatoes has been greatly improved in all sections of the State. However, the feeling is that the law, to be most effective, should not give growers the option of not grading or grading according to the adopted standard, but that potatoes offered for sale should be required to be graded and marked according to grade, namely, U. S. 1, or U. S. 2, and with the name of grower or shipper upon each package. Undoubtedly, the inspection service paid the two growers' organizations and the growers and shippers who made use of it. In a year when movement of cars to market was slow, sometimes taking more than a week above the usual schedule, the inspection certificate was

worth more than the two to four dollars which it cost, if for no other purpose than as a basis of settlement of claims with the railroads. Also, in a year of falling prices, determination of condition and grade, before departure of car, is most important to the shipper, as potatoes have largely to be rolled and sold while in transit or consigned.

Very close coöperation was maintained between the Market News Service and the Grading Service. Through inspectors, more loading point markets were reported and more market prices, based upon U. S. Grade 1 and U. S. Grade 2 quoted. A most effective market news service can only be maintained when its quotations are based upon products which have been uniformly graded and inspected to establish and maintain the uniformity of the grade. Only quotations are comparable from those markets which have provisions for maintaining the same standard of products.

This office provided the representative of the Bureau of Markets in charge of the Market News Service with an up-to-date list of potato growers. Statements and instructions in reference to grading potatoes were published on several occasions in the Market News Service Bulletin.

The grading service will also be applied to early sweet potatoes and late Irish potatoes this year, and possibly to late sweet potatoes, and next year to strawberries, cantaloupes and watermelons, and probably apples and cheese. A preliminary survey has been made to find out conditions at loading points to determine upon grades and regulations for cantaloupes. It is felt that even more drastic regulations than the present law probably permits must be applied to secure the proper grading of cantaloupes, and the condemnation and holding by the inspector of cantaloupes and melons which have been picked too green, as is provided for by the California law.

ASSISTANCE IN MARKETING FARM PRODUCTS

Assistance is rendered to individual farmers, shippers and buyers in marketing cotton, corn, soybeans, peanuts, hogs, cattle, sheep, wool, lambs, meat, potatoes, cabbage, and apples. The method followed in cotton is for farmers to send in samples, and for a representative of this division to take the samples to one or more buyers, and then the bids obtained are wired to the owners of the cotton for acceptance or rejection. About 2,500 bales of cotton were marketed in this way. Assistance to individual farmers in marketing farm products is given mainly by mail. Growers are furnished information as to prices and possible buyers on different markets. Lists of buyers are made up as a result of special surveys and furnished to shippers. In response to the inquiries of buyers lists of growers who have the farm products in question for sale are furnished. Wherever the need for a quick transaction exists correspondence is carried on by wire and confirmed by letter.

A considerable demand has developed for our Monthly Farmers' Market Bulletin, in which products are listed for sale. About 3,500 copies of the Market Bulletin were distributed, and 2,500 copies of the Weekly Price Report. The last two publications are of especial assistance to this office in keeping us informed of market conditions in North Carolina towns and counties. The work of collecting a list of purebred livestock and poultry breeders in the State has just been completed and will soon be published in the form of a Directory of North Carolina Breeders of purebred livestock.

PUBLICATIONS

Farmers' Market Bulletin.
Weekly Price Report.
Weekly Hog Market Quotations.
Monthly Review of Producers' Prices.
Monthly Financial Statement of North Carolina Credit Unions.
Articles published in newspapers on Cotton Grading, State Warehouse System, and Peanut, Livestock and Potato Markets.

Respectfully submitted,
Wm. R. Camp,
Chief, Division of Markets,
Acting State Warehouse Superintendent,
Superintendent of Credit Unions.

REPORT ON DRAINAGE

To the Director:

This report, for the year ending June 30, 1919, covers the investigational and experimental work of this division conducted under a coöperative agreement between the North Carolina Department of Agriculture and the United States Department of Agriculture.

Mr. F. O. Bartel was appointed drainage engineer for the North Carolina Department of Agriculture on December 9, 1918, during Mr. E. R. Baker's service in the army, and succeeded Mr. Baker to this position upon his resignation in the summer of 1919.

The investigational and experimental work is connected somewhat with the extension work, since much of the material and many of the locations for experiments are obtained as a result of extension work. Consequently the reports on these two phases of our work overlap.

FARM DRAINAGE

During the past year preliminary examinations, surveys, designs and reports for tile drainage systems have been made on 24 farms in 11 counties, comprising a total area of 1,200 acres. Approximately 12,000 feet of tile have been installed on these farms.

Thirty-six farms, situated in 19 counties, have been visited for the purpose of giving assistance in the location and construction of terraces to prevent hillside erosion; the total length of terraces laid out being approximately 230,000 feet, or 44 miles.

PRELIMINARY EXAMINATIONS AND RECONNAISSANCE

Six examinations of a preliminary or reconnaissance nature have been made and reports issued, covering a total area of 119,000 acres.

RUN-OFF DATA ON DRAINAGE CANALS

The gaging station for the determination of run-off on Third Creek, Iredell County, is still being maintained. Records of daily gage heights are complete from March 17, 1913, to date. In order to determine more accurately the distribution of rainfall on Third Creek watershed, four additional rainfall stations were established in June, 1919, which, in addition to the two at Statesville, N. C., makes a total of six on a watershed area of 44,000 acres.

STUDY OF EFFICIENCY OF UNDERDRAINS

The experiments started in November, 1916, on two of the tile drainage systems at Cotton Valley Farm, Edgecombe County, have been continued and are still in progress. Considerable progress has been made in assembling and plotting the data obtained and in summarizing the results in report form.

Similar experiments were started in April, 1919, on the J. T. Lewis Farm, Pitt County, on a different type of soil. The purpose of the experiments on both farms is to determine:

1. Amount of run-off from underdrained land.
2. Relation of rainfall to run-off.
3. Action of tile drains in lowering the ground water level.

EXPERIMENTAL MAINTENANCE WORK ON DRAINAGE CANALS

In 1917 about two miles of dredged canal through Jacob Swamp, Robeson County, was cleaned out and put in good order. The work was postponed in 1918 on account of war conditions, but was resumed again in May and June of this year on the same section. A summarized report of this work for the years 1917 and 1919 has been prepared. The purpose of this experiment is to study the best methods and cost of maintenance of drainage canals in the State.

In addition to the above classified lines of work, various special investigations have been made.

Respectfully submitted,

H. M. LYNDE,
Senior Drainage Engineer.

APRIL 1919 BULLETIN 239

THE TOBACCO FLEA BEETLE

Z. P. METCALF AND G. W. UNDERHILL

NORTH CAROLINA
AGRICULTURAL EXPERIMENT STATION
CONDUCTED JOINTLY BY THE
STATE DEPARTMENT OF AGRICULTURE
AND THE
NORTH CAROLINA STATE COLLEGE OF
AGRICULTURE AND ENGINEERING

RALEIGH AND WEST RALEIGH

THE NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION

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SUMMARY

The Tobacco Flea Beetle or "Flea Bug" is one of the worst pests of tobacco under North Carolina conditions. The injury caused by this insect consists of eating small holes through the leaves. This insect lives over the winter under leaves and trash, around the edges of tobacco fields or in adjoining woods. They come out of hibernation early in the spring and attack the young tobacco plants in the seed beds, and seriously injure them. Frequently it is impossible to get a stand of plants, because of the attacks of this insect. Later when the tobacco plants are transplanted to the fields they attack the plants and cause a weakened condition so that the plants die and have to be replanted. Still later in the season they attack the nearly matured leaves in the field, and while the damage they do at this season of the year is very extensive, it has not been noticed so much of late, because low grade tobacco has been selling at a relatively high price. Besides tobacco the tobacco flea bug lives on various weeds and cultivated plants belonging to the Nightshade Family, such as the potato, tomato, common nightshade, horse nettle and ground cherry.

The life history may be summarized as follows: The adults hibernate over winter, emerging as soon as any food plant is available in the spring. Usually they damage the tobacco beds very extensively at this time. The adult tobacco flea beetle is a small, active insect that feeds by eating holes through the leaves. The amount of green food that they eat is almost beyond belief, averaging ten times their own weight per day. This is equivalent to the average man eating about a ton of food per day, and the average cow eating five tons of food daily. The tobacco flea beetle hibernates only in adult stage under leaves, grass, etc., along the edge of the tobacco fields or other suitable places. They go into hibernation soon after the first killing frost, and continue there until food is available in the spring. Eggs are laid in the ground from April to September. They are laid near the surface of the ground usually under the tobacco plant, where they hatch in approximately a week. The eggs are very small. It would take sixty laid end to end or one hundred and twenty-five laid side by side to equal an inch. Larvae occur on the roots of tobacco from May to October. They are very small yellowish grubs about one-sixth of an inch long, when full grown. They live on the fine hairlike roots of the tobacco plant. It takes nearly two weeks for them to become full grown. The pupae are found in small cells just beneath the surface of the

ground under the tobacco plants. The control measures recommended in this bulletin are directed towards three main points. The control on the plant beds chiefly by dusting or spraying, dipping the plants at transplanting time, and the destruction of the suckers in the field. Other control measures are also discussed.

THE TOBACCO FLEA BEETLE

By Z. P. Metcalf and G. W. Underhill

The tobacco flea beetle has long been recognized as one of the most important insect enemies of tobacco in North Carolina. The senior author in a bulletin, published in 1909, accorded this insect first rank as a pest of tobacco. Since that time the amount of damage which it does has apparently increased, although the loss in a monetary way has perhaps decreased slightly, due to the fact that the poorer grades of tobacco sell for a relatively higher price today than ever before. While the damage in the field is thus compensated for, the damage in the beds is a serious problem which is ordinarily not appreciated by tobacco growers. The present bulletin has been prepared, therefore, to present to the farmer a discussion of this pest, and aims to point out to him the nature of the damage done by this flea-beetle, together with suggestions of proper control measures as well as a discussion of the life history of this insect on which the control measures are based, for without a clear understanding of the life history of the insect it is impossible to apply the proper remedies.

COMMON NAMES

This insect is known generally as the "flea-bug" by farmers in this and other states. Sometimes, although rarely, tobacco farmers speak of it as the "tobacco flea-bug." Strictly speaking, however, the insect should be called the tobacco flea-beetle, because it is a beetle and not a bug. The term "bug" should be reserved for insects such as the stink bugs, the terrapin bug, squash bug, etc. This distinction would hardly be worth insisting upon were it not for the fact that the true bugs are provided with piercing mouth parts by means of which they pierce the leaves and stems of plants and suck out their juices, whereas the beetles have chewing mouth parts and actually eat away the leaf or other parts of the plant. Regardless of this fact, tobacco farmers generally speak of the tobacco flea-beetle as "sucking the plant." With these reasons in mind the name "Tobacco flea-beetle" is used throughout this report, as this is the only name that is distinctive.

DISTRIBUTION

The accompanying maps will show the distribution of this insect as far as the records show. Apparently it is rather widely distributed in the tropical and temperate regions of the world. Outside of the United States we have records of its occurrence in Canada, Mexico, Panama, Cuba, Bahamas, Porto Rico, Ceylon, and the Philippine Islands. In the United States the insect perhaps occurs wherever tobacco is grown. The

FIG. 1—Map of the world, showing recorded distribution of the Tobacco Flea Beetle. (Original.)

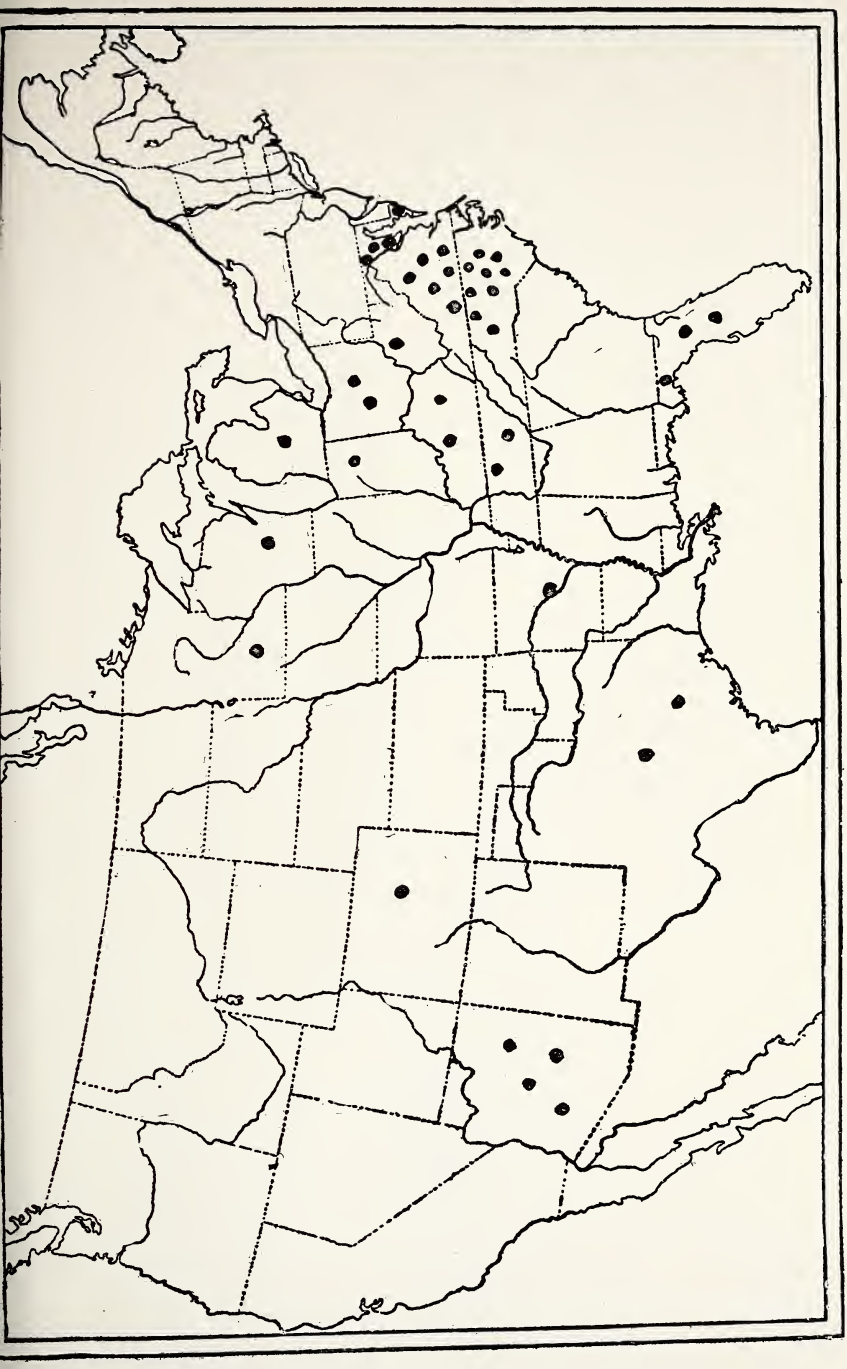

FIG. 2—Map of the United States, showing distribution of the Tobacco Flea Beetle. (Original.)

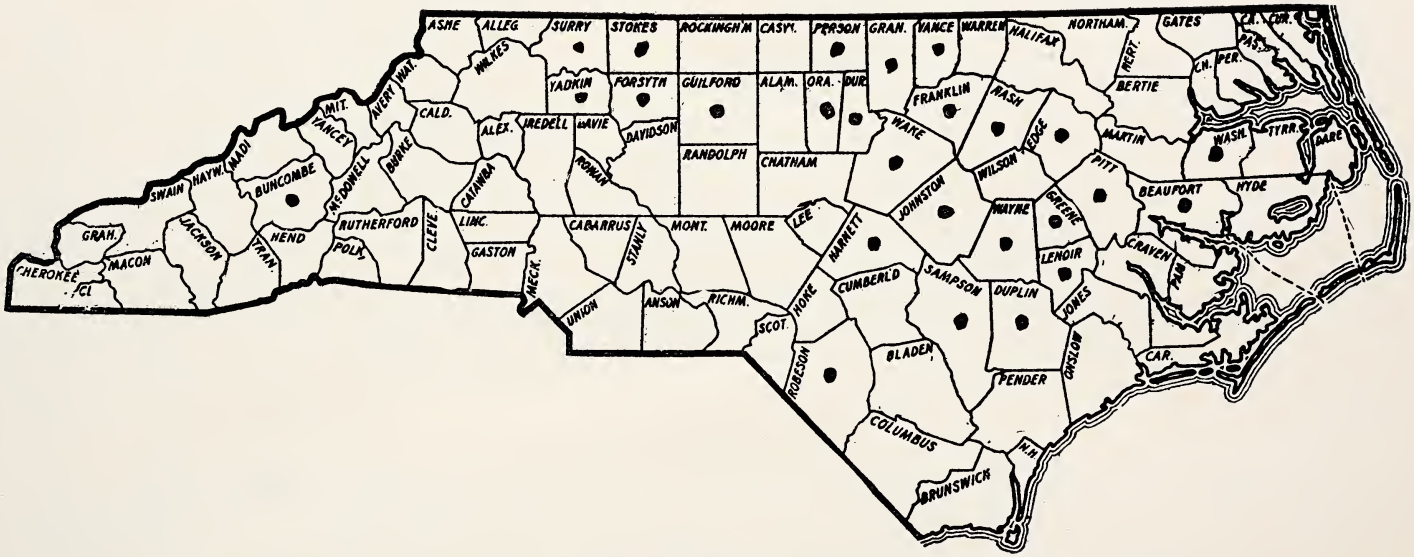

FIG. 3—Map of North Carolina, showing the recorded distribution of the Tobacco Flea Beetle. (Original.)

maps will show the actual records. In North Carolina it has been found wherever there has been an opportunity to examine the growing tobacco. It is presumed, therefore, that it occurs throughout the State.

HISTORY

The tobacco flea-beetle was originally described by Fabricius in 1801, and has long been recognized as an important insect pest of tobacco in America. It has been discussed by all of the writers who have treated of the general subject of tobacco insects, especially Howard 1898, Metcalf 1909, and Morgan 1910.

IMPORTANCE OF THIS INSECT

The tobacco flea beetle is without doubt the most important insect pest of tobacco in North Carolina. It is given this rank for the following reasons: First, because it damages the tobacco in the plant beds as well as in the field. There is no other insect enemy of tobacco of prime importance that damages both the young plant in the bed and the growing crop. The tobacco flea-beetles commence their attacks almost as soon as the plants come up, and continue them as long as the plants are growing in the field, and, not infrequently, they follow the harvested crop to the barns where they continue their attacks until excessive heat kills them or drives them out. In the second place, the small size of the insect, together with the large number of individuals which occur, makes the tobacco flea-beetle a very difficult pest to control. In the third place, the effect of the flea-bugs' work is to lower the grade of the tobacco. This is effected by actual reduction in the weight and "body" or quality of the leaves which have been damaged by the flea-beetle. The result is that the tobacco farmer not only produces fewer pounds of tobacco, but the damaged tobacco is placed in a lower grade which sells, even at the present high prices, for much less per pound than tobacco which has not been damaged.

INJURY OFTEN MISTAKEN FOR THAT OF THE FLEA-BEETLE

The adults of the corn bud worm, or root worm *(Diabrotica 12-punctata)* are sometimes found feeding on the plant beds, and frequently they are found feeding on the plant leaves in the field. These punctures might be mistaken for those of the tobacco flea-beetle, but they are much larger. There are two black flea-beetles in practically every field in very small numbers; a medium large black one *(Chaetocnema protensa),* and a small one which is the potato flea-beetle *(Epitrix cucumeris).* Only a few of these are to be found, and they seem to disappear in the latter part of the season. Grasshoppers often do much damage, especially the little grouse locusts *(Tettigidae lateralis),* which make

small holes resembling the flea-beetles' injury. Also in the plant beds plant hoppers *(Membracidae)* and leaf hoppers *(Jassidae)* are often very plentiful. Their feeding punctures might be attributed to the beetles also, but none of these do much damage, and are hardly worthy of any consideration in connection with the flea-beetles.

FOOD PLANTS

The tobacco flea-beetle feeds by preference upon any and all of the members of the *Solanaceae,* or Nightshade, family. The plants of this

FIG. 4—The Horse Nettle. A weed which is a favorite food plant of the Tobacco Flea Beetle. (Original.)

family are its natural hosts. The authors have found them feeding on the following named members: the potato *(Solanum tuberosum),* the wonder berry *(Solanum nigrum* variety), horse nettle *(Solanum carolinense),* the black or common nightshade *(Solanum nigrum),* the egg plant *(Solanum melogena), the tomato (Lycopersicum esculentum),* the ground cherry or husk tomato *(Physalis pubescens),* the jimson or Jamestown weed *(Datura stramonium),* the sheep bur *(Solanum rostratum),* and the tobacco *(Nicotiana tabacum).* Of these, the beetle seems to prefer the tobacco among the cultivated plants, and the husk tomato among the wild plants.

In the field in spring and late fall, when there are no tobacco plants on which the insects could feed, the authors have found the beetles feeding on the following plants, other than of the Solanaceous family: cabbage and turnip of the Cruciferae family; eaten a little around the edges of the plant beds; the frost flower weed (Aster sp.), the butter weed *(Erigeron canadensis),* the butterfly weed *(Asclipeas tuberosa),* are all among the plants on which a very few beetles were taken in the early spring. In the fall pokeweed *(Phytolacca decanda),* and the cowpea *(Vigna sinensis)* were relished very much when no better host plant was near. A few beetles have been taken on a thistle. None of the above plants were much relished, and were simply used temporarily to tide over a short period until more desirable plants were available.

FIG. 5—The Husk tomato. A favorite wild food plant of the Tobacco Flea Beetle. (Original.)

In the laboratory the susceptibility of several plants was tried out. Young tender leaves were placed in cages with the beetles. They ate the sheep sorrel, morning glory, and violet leaves a very little, and, apparently, would not feed on beans, corn, plantain, clovers, honeysuckle, and dewberry.

FIG. 6—The Jimson or Jamestown weed. A common weed which furnishes an abundance of food for the Tobacco Flea Beetle. (Original.)

NATURE OF DAMAGE

The damage to the tobacco plant consists of eating small holes either partially or entirely through the leaves. In the tobacco beds the tobacco flea-beetles not infrequently, if left undisturbed, check the plants so severely that it is often quite impossible for the farmer to secure enough strong plants for transplanting. Even if enough plants are secured, it frequently throws the season for transplanting so late that the plants do not mature well in the field. Hence the crop is cut short.

Another factor that should be taken into consideration, in this connection, is the fact that the late tobacco is damaged much more by the flea-beetles than all other kinds of tobacco insects. Not infrequently, the beds will be so badly damaged that they will be abandoned by the farmer, thus resulting in a complete loss of labor, fertilizer and seed. Although tobacco growers generally are familiar with the work of the tobacco flea-beetle in the field, very few appreciate that it is the same insect which damages the bed. The damage on the beds is usually

attributed to the various kinds of flies which are found abundantly in tobacco beds. These flies are much larger than the tobacco flea-beetle and are readily observed because they usually light on the cloth or on the upper sides of the leaves when the cover is removed, while the flea-beetles have the habit of dropping to the ground when they are disturbed. These flies are of various kinds, and, so far as observed, they all belong to species which breed in stable manure which is commonly used as a plant bed fertilizer. None of these flies feed on growing plants, hence they can do no damage to the plants in the beds.

LIFE HISTORY SUMMARY

The following summary is based on the data given in the following pages. The adults hibernate over the winter (Fig. 7), going into hibernation soon after the first killing frost. The latest recorded date is

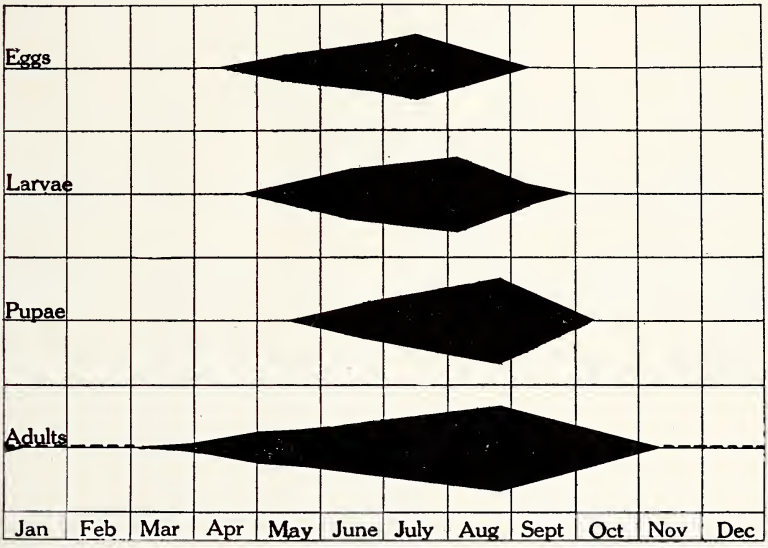

Fig. 7—Summary of the life history of the Tobacco Flea Beetle, showing months in which the various stages occur, also their prevalence. The different broods are not taken into consideration. (Original.)

November 7. They begin to emerge early in the spring, coming out just as early as the plants appear on the beds, and continue to collect on the beds until transplanting time. The first brood of adults appears about the last of May, and the numbers of adults increase until harvest time. From harvest time the numbers decrease rapidly until they are driven into hibernation.

The adults begin to lay eggs very soon after they emerge in the spring. The earliest recorded date is April 17. Large numbers are laid by the last of May, and the maximum is reached during June and July. After the middle of August very few eggs are found.

The first larvae hatch about the first of May. The greatest numbers occur in June and July. In late August they are much less numerous. The latest one taken was October 3.

The first pupae appear about May 15 or 20. The number increases rapidly throughout June. They are most abundant from June to late August. The latest date on which they have been taken is October 3.

The evidence shows that there are at least four broods of the tobacco flea-beetle in the eastern part of the State, but the broods overlap so much that they are difficult to follow.

THE EGG

DESCRIPTION

The egg (Fig. 8) is elongate-ellipsoid and is generally a little pointed at one end, and broadly rounded at the other. Its shape may be changed

FIG. 8—Egg of Tobacco Flea Beetle greatly enlarged. (Original.)

to accommodate itself to other eggs and to the surrounding surfaces. Just after the egg is laid the color is pearly white, but as it grows older it becomes more and more yellowish until a medium-light lemon yellow color is assumed, which is due to the developing embryo. Under the microscope the surface shows a distinct sculpturing. These very small somewhat irregular depressions cover the chorion, and give it a sort of network appearance. The size of the eggs varies considerably.

FIG. 9—Leaf of Tobacco plant, showing injury. (After Metcalf, N. C. Dept. Agr.)

The length is usually about two and one-half times the width. The average size of 25 eggs taken at random throughout the season was as follows: average length .4095 mm. (about 1-60 of an inch), and average width .1806 mm. (about 1-125 of an inch).

The eggs of the tobacco flea-beetle are laid on, or very near, the sur-

face of the ground immediately under the host plant. Occasionally a few eggs may be deposited on the body of the stalk at the surface of the soil, but this condition is very rare. No eggs were ever found in the field on the leaves of the plants.

The period of incubation of the eggs hatched under laboratory conditions ranged from 6 to 8 days in midsummer. The majority of the eggs hatched in 6 to 7 days. Moisture and temperature greatly influence the length of the incubation period, thus early and late in the season the incubation period would extend to nine days or more. The average, under field conditions, is assumed to be about 7 days.

The data on the number laid by each female under laboratory conditions shows a daily average of 2.21 eggs. While no definite data was obtained on the length of the active life of a female beetle, it is assumed that they live for at least 90 days, thus an average female would lay about 200 eggs during the season under normal field conditions.

THE LARVA

GENERAL DESCRIPTION

The larvae of the tobacco flea-beetle are filiform, and contain twelve segments. Each segment is about the same diameter except the last one, which is smaller. The thoracic segments each bear a pair of short segmented legs. The remaining segments are legless. The ultimate segment (Fig. 13) has a pair of pro-legs, by means of which the larva is able to cling to surfaces which are comparatively smooth. There are nine pair of spiracles: one pair on the pro-thorax and eight pair on the abdominal segments 1-8, located just above a slightly prominent lateral longitudinal fold on the segments. The spiracles are rather inconspicu-

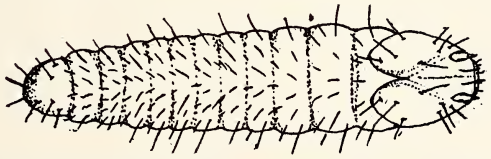

FIG. 10—Newly hatched larva of the Tobacco Flea Beetle, greatly enlarged X 100. (Original.)

ous, because there are no distinctly colored lips or borders to them. The color of the larvae is dirty white, except the head, which is "honey yellow" with dark reddish brown mouth parts. The mandibles are tridentate and of a very dark brown color. The hairs are somewhat irregularly in two rows around each segment.

Immediately after hatching (Fig. 10) a larva is less than one mm. long (.50 to .75 mm. long; .12 to .15 mm. wide); nearly cylindrical, somewhat flattened dorso-ventrally; milky white in color, except the head, which is yellowish brown in color. The head at this age is very long and considerably flattened dorso-ventrally. In proportion to the

rest of the body it is much longer, broader, and flatter than at any other stage. The head nearly equals the length of the three thoracic segments. This difference in proportion of head to the body lasts only for a short period of time. Also the body which is somewhat flattened and broader, in the middle region, becomes more and more cylindrical after the first day, until the normal proportions are assumed about the third day.

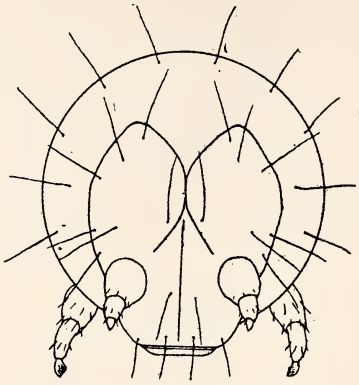

FIG. 11—Head of larva of Tobacco Flea Beetle, showing arrangements of hairs. (Original.)

The hairs on the body appear more thickly crowded and longer at this stage than any other.

The length of the average larva when about one week old is about 3.5 mm., and the thickness about .35 mm.

The cephalic lobes are very distinctly separated by a rather prominent medial suture which reaches from the dorsal margin of the epicranium, down the middle of the frons, to the margin of the inconspicuous clypeus. Each lobe of the epicranium is pointed posteriorly (Fig. 11). Two diverging sulci extend from the middle of the epicranium outward and downward nearly to the base of the rudimentary antennae. These sulci

FIG. 12—Larva of Tobacco Flea Beetle, showing general characters enlarged X 15. (After Metcalf, N. C. Dept. Agr.)

gradually become evanescent near the antennae. There are seven hairs on each lobe of the epicranium and the gena above and posterior to the diverging sulca. (Frontal view.) There are four hairs on each half of the frons. (See Fig. 11 for the arrangement of the hairs.) The clypeus is very short dorso-ventrally and nearly straight on the dorsal margin

and slightly concave on the ventral margin. The labrum is broadly semicircular, the ventral border being truncate and slightly lobed. There are four hairs in a row running transversely across the face of the labrum. The mandibles are strong, dark brown in color, and each has a tri-dentate cutting edge. They are set far apart and are short and robust so that the

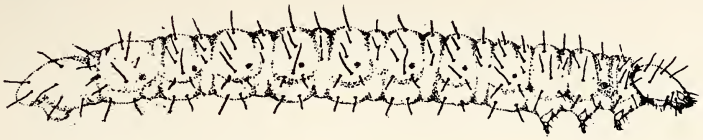

Fig. 13—Larva of Tobacco Flea Beetle, showing arrangements of hairs. Enlarged X 20. (Original.)

cutting edges do not overlap as they do in the adult. The maxillary palpi are apparently four jointed; the labial palpi three jointed. The mature larva has an average length of 4.23 mm.

As the result of a study of the habits of the larvae, under field conditions, it was found that they feed upon the roots of the plants of the Solanaceous family. No larvae were ever found outdoors feeding upon the leaves. In special cases it has been found they not only feed upon, but often tunnel the stalks of tobacco and ground cherry plants for a distance of several inches. This is especially noticeable if the plants are accidentally partly buried.

In the field the larvae were normally found only in the ground among the fine rootlets (Fig. 14). They were limited to this root zone, and fed largely upon the fine rootlets. Occasionally a large root was girdled or tunneled, and thus greatly weakened or completely ruined. It is reasonable to conclude that considerable damage is done by the larvae of the tobacco flea-beetles where they are in large numbers. Granting that they are very small and their feeding capacity very limited, it must be admitted that the sum total injury to the tobacco crop in the State, during the growing season, is no small item.

The feeding zone of the larvae is limited. Nearly all were found within a radius of ten or twelve inches of the plants, and feeding on the small rootlets (Fig. 14) near the surface at an average depth of less than one inch. It was found that the cultivation, the moisture content of the soil, and the amount of shade given by the bottom leaves, each influenced the limits of the feeding zone, both as to the distance from the stalk and the depth in the ground. The extremely hot sunshine in August drove the larvae much deeper in the soil, especially after the bottom leaves had been primed off. This suggests the advisability of having the rows wider apart, and of priming off the bottom leaves when the crop is laid by, so as to admit as much sunshine as possible. This practice would greatly lower the percentage of eggs that hatch, and also make it unfavorable for the development of the larvae that did hatch, thus greatly increasing the mortality. Priming off the bottom leaves is already a common

FIG. 14—Tobacco stalks showing the small rootlets on which the Tobacco Flea Beetlelarvæ feed. (Original.)

practice with some farmers, but it is not used with any idea of checking or controlling the flea-beetle. This is a method of field control that can be safely followed.

The exact length of the larval stage from hatching to pupation has not been determined. Every method that could be devised has been tried without any success. Larvae have been kept under laboratory conditions for twelve days, where they reached an average length of 4 mm., but they all died before pupating. Numbers of larvae of the same average size were collected in the field and placed in breeding cages where they pupated in from four to five days. These figures added to the life of the larva, as indicated above, would give the length of the larval stage as from fourteen to sixteen days. These figures are approximately the same as those determined by Chittenden 1899.

THE PUPA

GENERAL DESCRIPTION

When the larva is about ready to transform to the pupa a simple, crude pupal cell is made about one-half to one inch deep in the soil. The cell is formed by contortions of the body. In this cell the larva becomes

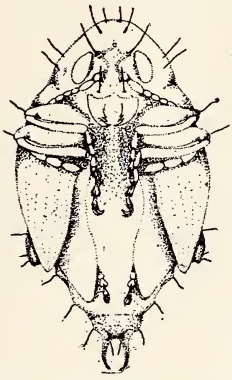

FIG. 15—Pupa of Tobacco Flea Beetle. Ventral view much enlarged. (Original.)

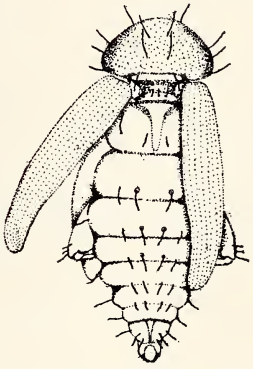

FIG. 16—Pupa of Tobacco Flea Beetle. Nearly mature. Much enlarged. (Original.)

inactive and changes to the pre-pupa. The length of the prepupal stage is estimated to be about 30 to 36 hours.

The general appearance of the tobacco flea-beetle pupa is very typical of the Chrysomelids (Figs. 15 and 16). The head is directed sharply caudad with the frons nearly in straight line with the ventral surface of the abdomen. The mouth-parts lie partly over and between the first tarsal joints of the pro-thoracic legs. The antennae extend caudad, and are bent underneath the pro- and mesothoracic legs. The antennal segments 5 to 8 are completely invisible under the legs, while segments 9 to 11 point toward the mesal line, and lie posterior to and almost parallel with the tibia of the mesothoracic legs. The elytra are folded tightly on the ventro-lateral surfaces of the abdomen. The wings lie underneath

the elytra and more ventral. The legs are each folded with the femur pointing away from the mid-line and the tibia toward it. The tarsi are directed caudad along the mesal line. The pro- and mesothoracic legs are folded close together directly ventral to their respective thoracic segments. The metathoracic legs are folded considerably caudad to these and the wings lie ventrad across the femur and tibia of each. The abdomen is composed of seven distinct segments, with a very characteristic pair of anal hook-like appendages. Each abdominal segment has four distinct setae on the dorsal surface, and one prominent seta on each lateral edge. Also the thoracic segments have rather distinct setae on the dorsal surface. The pro-thorax has twelve setae. See Figs. 15 and 16 for all of the above characteristics and arrangement of the setae.

The very young pupae are larger and more slender than the older ones. The average length of the pupa is 1.75 mm., and the width across the meta-thoracic femur is .85 mm.

The first pupa was found in the field on July 16. They had been overlooked up to that time. The last one found was on October 3, in an old plant bed. Throughout August they were easy to find, but in September they began to get very scarce.

In order to get the exact time of pupation, larvae were collected and kept until they changed to the pupal stage. The best results in rearing pupae were obtained by the use of one-half inch glass tubes about two inches long open at both ends. These were filled loosely with dark loamy soil, and one end buried in sand in tin boxes. The sand in the tin boxes was watered and the soil in the tubes kept moist by the capillary rise of water, thus it was easy to control the moisture content. The nearly mature larvae were placed in these tubes with a piece of cheese cloth tied over the top. Usually the pupal cells were made about one-half inch deep in the soil. It was easy to get exact records from these tubes.

The following table shows the average length of the pupal stage as determined during the summer (1917).

TABLE I

SHOWING THE LENGTH OF THE PUPAL STAGE

No. of Pupa	Date Pupated	Date Emerged	Length of Pupal Stage (No. Days)
1	7/22	7/26	4 days
1	7/26	7/31	5 days
2	7/26	7/30	4 days
2	8/9	8/13	4 days
5	8/13	8/17	4.5 days
1	8/14	8/18	4 days
1	8/16	8/20	4.5 days
1	8/17	8/22	5 days
1	8/17	8/23	5.5 days
1	8/18	8/23	5 days
2	8/21	8/25	4 days
2	8/23	8/27	4 days

Average length of the pupal stage 4.46 days.

ADULT

GENERAL DESCRIPTION

The adult tobacco flea-beetle (Figs. 17 and 18) is very small, averaging from 1.5 to 2 mm. in length. Its dull reddish-yellow color, with the irregular dark fuscous patch across the middle of the elytra is distinctive.

Blatchley (1910) gives the following description: "Oblong-oval, subconvex. Dull reddish-yellow; elytra often with a fuscous transverse cloud at middle; abdomen brown, antennae and legs pale reddish-yellow, the four outer joints of former and hind femora of latter often darker. Thorax convex, shining, nearly twice as wide as long, not narrowed in front; antabasal impression evident but not deep; surface distinctly but

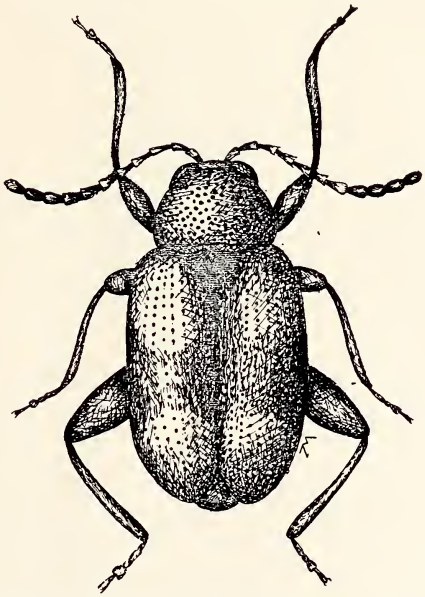

FIG. 17—Adult of Tobacco Flea Beetle. Much enlarged. (After Metcalf, N. C. Dept. Agr.)

rather finely and sparsely punctate. Elytra very little wider than thorax, umbone feeble, punctures rather coarse and not crowded on disk; finer and more close set on sides, where the intervals are subconvex. Length 1.5-2." (See Fig. 17)

In addition to the above the following details are added:

Head.—Vertex very finely and somewhat sparsely punctate without hairs, except a patch of four setae on each side just above the oblique ridges on one of the "V" on the face and mediad to each eye. The frons and frontal carina have several hairs arranged as shown in Fig. 19. A row of eight setae just dorsal to the clypeal suture, and a row of four

prominent bristles extends across the small blunty rounded labrum near its ventral border. Each gena has several bristles or hairs on the sides below the eyes. The antennae are eleven jointed. The first segment is about twice the size of the second, both of light reddish-yellow color; segments three to six, inclusive, are smaller, more slender, and of a light golden yellow color; segments seven to eleven, inclusive, are larger and gradually darker towards the tip; the eleventh segment nearly black, with the end pointed and nipple-like. All the segments are pubescent.

Mouthparts.—The mandibles are very strong and overlap for about half their length. Each has five prominent teeth, curved rather sharply inward. The maxillae are rather small, palpi four jointed, the lacinia

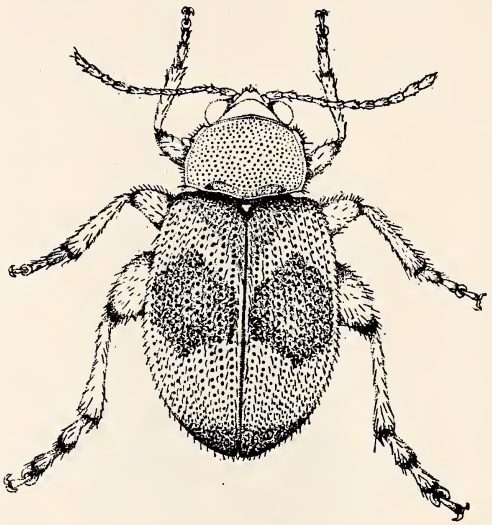

FIG. 18—Adult of Tobacco Flea Beetle, showing the arrangements of hairs. (Original.)

has a thick tuft of rather long coarse bristles across the broadly truncate free end, which makes these very efficient appendages for catching and holding the bits of leaf tissue cut off by the mandibles. The labium is very small with a rather inconspicuous three jointed palpi.

Thorax.—Reddish golden-yellow, strongly convex, dorsal surface shiny, rather shallowly, coarsely and sparsely punctate; front angle obliquely truncate with a small tooth and a prominent seta at the posterior limit of the angle; the lateral border narrowly margined and slightly serrate along the edge with several bristles at almost regular intervals; antebasal impression is shallow but evident.

Elytra.—Light yellow in color, transparent, except for a fuscous band across the middle. There is a distinct dark triangle behind and to the sides of the scutellum, and a dark area over the last abdominal segment. These areas are not covered by the wings, which are folded underneath the elytra, thus the dark reddish dorsal surface of the abdomen shows

through the transparent elytra. Ten striae of coarse punctations are on each elytra; each subconvex interval has a row of semierect hairs; the inflexed sides are serrate along the entire length; the teeth are semicircular in outline with spaces between about equal to the width of the teeth.

Abdomen.—Five segmented; first segment almost equal in length to all the rest, coarsely punctate and alutaceous on the ventral surface; second, third, and fourth segments narrow, all three about equal to the fifth in width, each finely and sparsely punctate; fifth segment narrowed

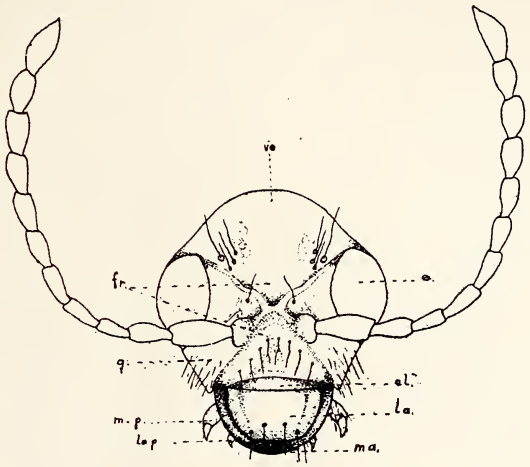

FIG. 19—Front of head of adult Tobacco Flea Beetle, showing arrangements of hairs. (Original.)

behind with the genital and anal plates at the tip; ventral surface pubescent.

Legs.—The legs are reddish-yellow except the femora of the metathoracic legs which are darker, reddish-brown. The hind femur is extremely well developed for leaping, and the tibia of this leg has a prominent sharp spur on the distal end. The tarsi are all apparently four jointed.

HABITS OF ADULTS

The tobacco flea-beetle is a leaf-eating insect, and it is the adult that does most of the damage. All flea-beetle injury is characterized by small round, or irregular feeding punctures scattered over the leaf surface, or by a more or less complete skeletonization of the leaf. The last brood of the tobacco flea-beetle skeletonizes the leaf to some degree, but ordinarily the injury is in the form of small round holes. These feeding punctures may be cut partly or entirely through the leaf.

On the plant bed the beetles feed principally on the under side of the leaves. Most of the punctures observed on young tender plants are appa-

rently cut from the under side. (Fig. 20 shows this point very well.) Often a leaf that shows very little or no damage from above will show considerable signs of feeding on the under side. When infestation is general and the plants are small, the whole plant may be devoured.

After the plants are transplanted, and before they begin to grow, the beetles feed on the under side of the leaves, principally those that are somewhat rolled or folded, and those that lie on the ground. If many

FIG. 20—Under surface of young tobacco leaves, showing feeding punctures. (Original.)

beetles are present the entire leaf surface will soon be shot full of holes, and the leaf will commence to dry up. They usually continue to feed on these leaves as long as there is any green tissue, and plants are frequently killed by the attack of the beetle at this time.

Just as soon as growth begins and the tender leaves grow out, nearly all feeding is shifted to the new growth. The beetles were rarely ever seen feeding on the bud leaves.

As the plants grow and as the sun gets hotter in mid summer, the feeding is confined to the lower leaves almost entirely. Very few beetles do much feeding above the middle of the plant. It is believed this is due to the fact that the beetles are provided with better shade.

In the latter part of the season, after housing (or priming) has begun, particularly in young tobacco, the feeding becomes very general on all leaves, even the tips. On older tobacco the beetles seem to collect and

feed principally on the stipules of mature leaves close up to the main stalk, or on the tender suckers. Very often the main stalk will show very much sign of chewing, indicated by irregular dark areas.

The leaves that nearly touch the ground seem to be perferred by the beetles. They often collect on such in large numbers. The folded leaves are usually eaten so badly that they soon turn yellow and dry up prematurely.

The beetles feed nearly anywhere on the leaf surface, but apparently the majority of the holes are near the margin of the leaves. The beetles are less active in cool weather in early spring, and late in the fall, than they are during the heat of the summer, although the damage that they do may be more noticeable at this season of the year, because the plants are not growing rapidly. The beetles are more active during the middle of the day than early in the morning or late in the evening. This is especially noticeable early in the season when the nights are cool.

THE AMOUNT EATEN DAILY BY EACH BEETLE

The amount of damage done by these beetles in the field is not realized by the average farmer. In fact, it is very difficult to estimate its extent, because there are several factors that come in. Some of these are: (1) the check upon the growth of the plant in the field, thus greatly lowering the average number of pounds per acre; (2) the increased spread of fungus diseases in the field by the beetles, and the giving of spores a good starting place in the feeding punctures made; (3) a possible bad effect upon curing the tobacco after it is put in the barn; and (4) the effect upon the price when put on the market. An estimation of some of these could not be made, but it was thought possible to approximately estimate the amount eaten.

In order to determine this amount, tobacco leaves that had previously been weighed were placed in cages containing a known number of adults. At the same time leaves which had been slashed with scissors were placed in cages without beetles to act as a check on evaporation. The two sets of leaves were removed from the cages every twenty-four hours and carefully weighed. The difference in the weight of the leaf before being placed in the cage with the beetle and at the end of twenty-four, minus the percentage of evaporation, divided by the number of beetles, has been taken as the amount eaten by each beetle. In all 743 beetles were used, and the average amount eaten by each beetle was 10.3 times its own weight. If each beetle eats this amount of green tobacco daily, and we assume that in an average infestation there are 15-20 beetles to the plant, each one feeding actively for a period of 100 days, then with 5,000 plants per acre, the total amount of green tobacco eaten by the beetles each season would be about *100 pounds per acre.* If it is assumed further that only 20 per cent of this weight is marketed in well cured

tobacco, which is worth .35 per pound, there is a direct loss of $7 per acre.

The above estimate is believed to be very conservative, and takes into consideration only one factor. Probably the greatest damage done by the beetles is in checking the growth of the plants, which have to suffer from the attack of these beetles from the time they come up on the plant-bed until mature in the field. The second factor in importance is the loss in quality of the marketable tobacco. A great loss also comes from an irregular stand of plants in the beginning of the season, and the necessity of resetting. The direct loss in pounds actually eaten by the beetle is certainly not as important as any of these.

HIBERNATION

The tobacco flea-beetle passes the winter only in the adult stage. The first severe frost in autumn forces the adults to go under grass, leaves, trash, etc., for protection. The exact date the beetles go into hibernation will vary somewhat, according to the two great controlling factors, temperature and food supply. However, they begin to collect under cover after the first killing frost. Some remain in the field as long as there is any green food. They have been found in the field as late as November 7th.

In the past two years we have taken screenings from late fall to early spring (Fig. 21). These were taken from places of every character that were thought to be suitable for insects to hibernate. These places were selected around the edges of tobacco fields and near old plant beds, both on high, well-drained land and on low land. The largest numbers of beetles were always taken along edges of woods adjoining the tobacco fields. Very few were taken more than twenty-five yards from the edge of the fields. These screenings were then placed in a covered battery jar and the jar placed in the warm sunshine. The beetles readily crawled up the sides of the jar where they could be secured very easily. The largest number taken in screenings was about 200 beetles per peck of leaves. These were secured early in the fall just after the first killing frost.

TIME OF EMERGENCE

The tobacco flea-beetles are more or less active all the winter. The time of emergence in the spring seems to be largely determined by the food supply. Just as soon as any host plant appears near their hibernating places, these beetles attack it.

The earliest food plants to appear in the spring are the tobacco plants in the seed bed. These are attacked by the time the largest leaves are about the size of a dime. At first only a few beetles are to be found on the bed, but their numbers gradually increase as the season advances. Most of these appear within a period of three or four weeks.

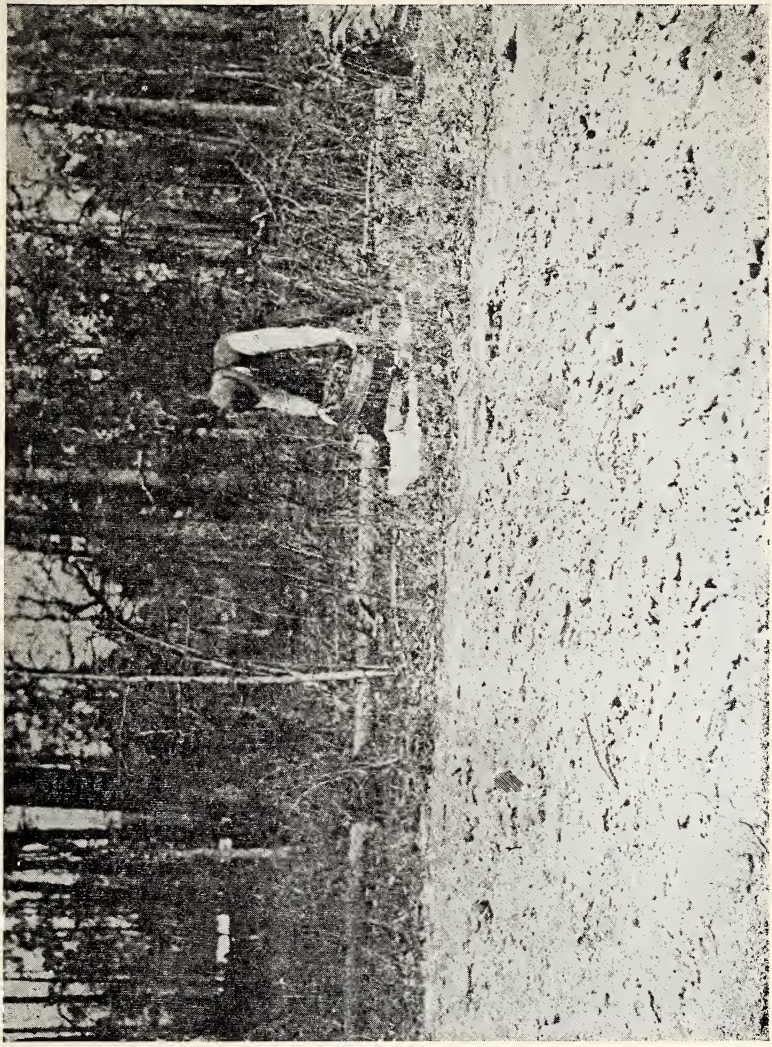

FIG. 21—Screening for the Tobacco Flea Beetle to determine its prevalence in winter. (Original.)

CONTROL MEASURES

The following control measures are recommended on a thorough study of the life history of the tobacco flea-beetle, and are believed to represent the best methods of attacking this pest. Special emphasis is laid upon three methods of attack: (1)The control of the insect on the plant in the bed, (2) the control of the insect at transplanting time, and (3) the destruction of the suckers after the crop is harvested. Not much emphasis has been placed upon the spraying of the plants in the field, for this method will not be necessary if the other methods are followed.

CONTROL OF THE TOBACCO FLEA-BEETLE ON THE PLANT BEDS

The control of the tobacco flea-beetle on the plant beds is thought to be the one most important thing that tobacco growers can do towards controlling the pest. As stated before (page 28) practically all of the hibernating beetles attack the plants on the plant beds. Therefore a control of this insect here accomplishes two important results: (1) It insures a crop of good strong plants, and (2) it destroys the beetles so that they cannot attack the plant later in the field.

The following recommendations for the treatment of the plant beds are based on a consideration of the importance of controlling the tobacco flea-beetle on these beds:

PLANT-BED TREATMENT

1. Locate the beds as far as possible from good hibernating quarters. If the plant-bed land is limited, and desirable locations are not to be had, be certain to burn a large area around the beds. Do not have surroundings like Fig. 24 without cleaning up and burning all the trash. If the beetles were abundant the previous season in the vicinity, take a favorable time and burn over the land for one hundred yards or more all around the beds. It is better to go too far than not far enough. The time to do this burning is preferably in the early winter, never later than the last of February.

2. Provide a good board frame and a tight beetle proof cover (Fig. 22); use only the best grade canvas, or use cheese cloth. Bury the boards in the ground a little and fasten on the canvas securely with strips, or stick it with tanglefoot or roofing paint. If the cover is not beetle proof, which condition is hard to obtain against this little active beetle, it can be made at least rather difficult for many to enter. The number attacking the plants before they begin to grow will be greatly reduced.

3. Provide a trap bed, or beds, near by the main bed on which the beetles may collect, and dust or spray this area thoroughly every week.

4. If the above precautions are not observed, or if the beetles get on

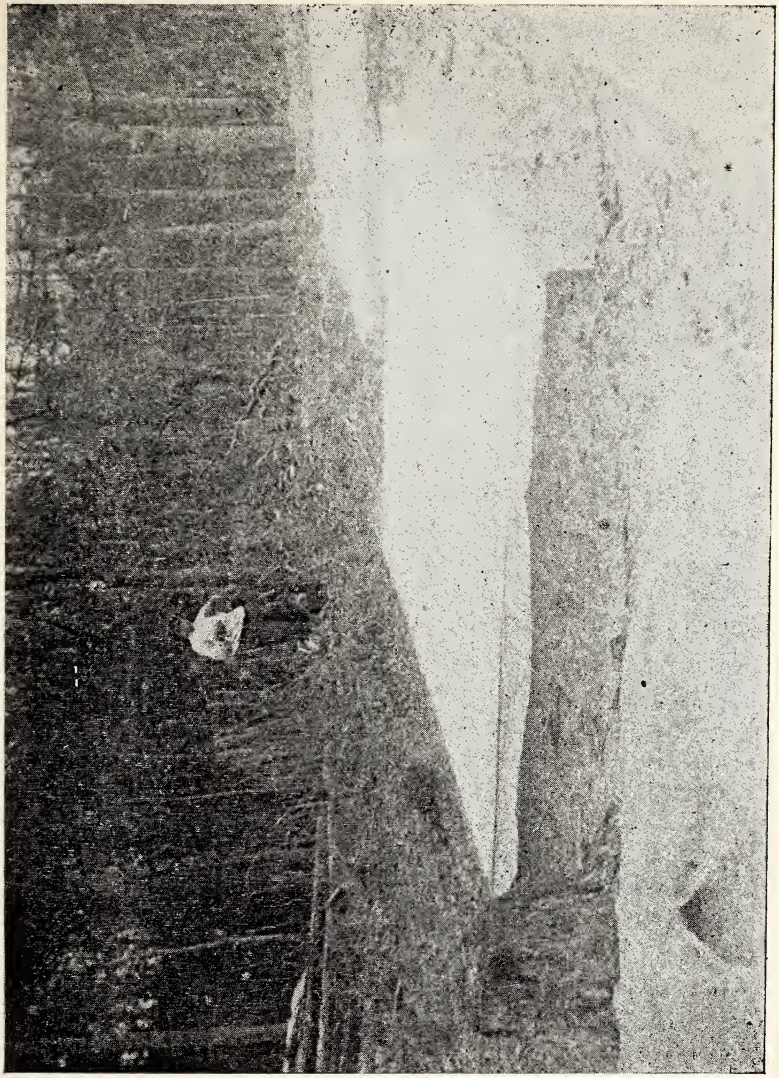

FIG. 22—A tobacco bed with a tight cover and a frame made of planking. A bed constructed in this way will go a long way towards controlling the Tobacco Flea Beetle. (Original.)

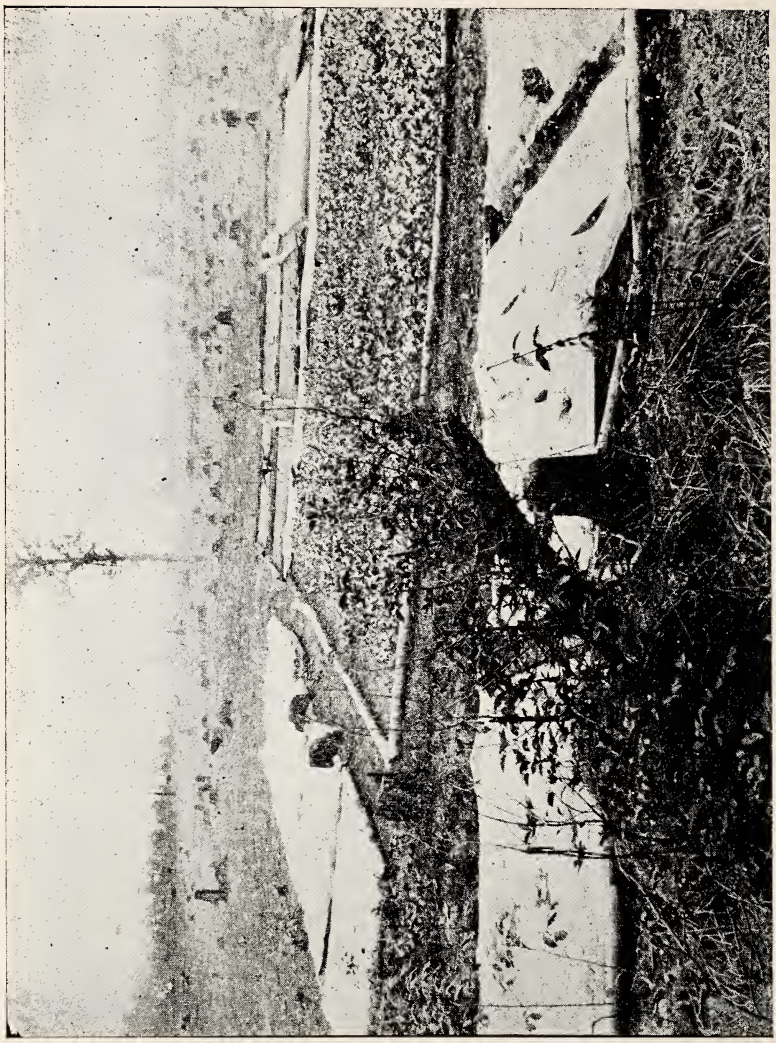

FIG. 23.—Experimental beds. The large uncovered bed in the center was used as a check; the smaller beds surrounding the large bed were used to test various ways of dusting and spraying. (Original.)

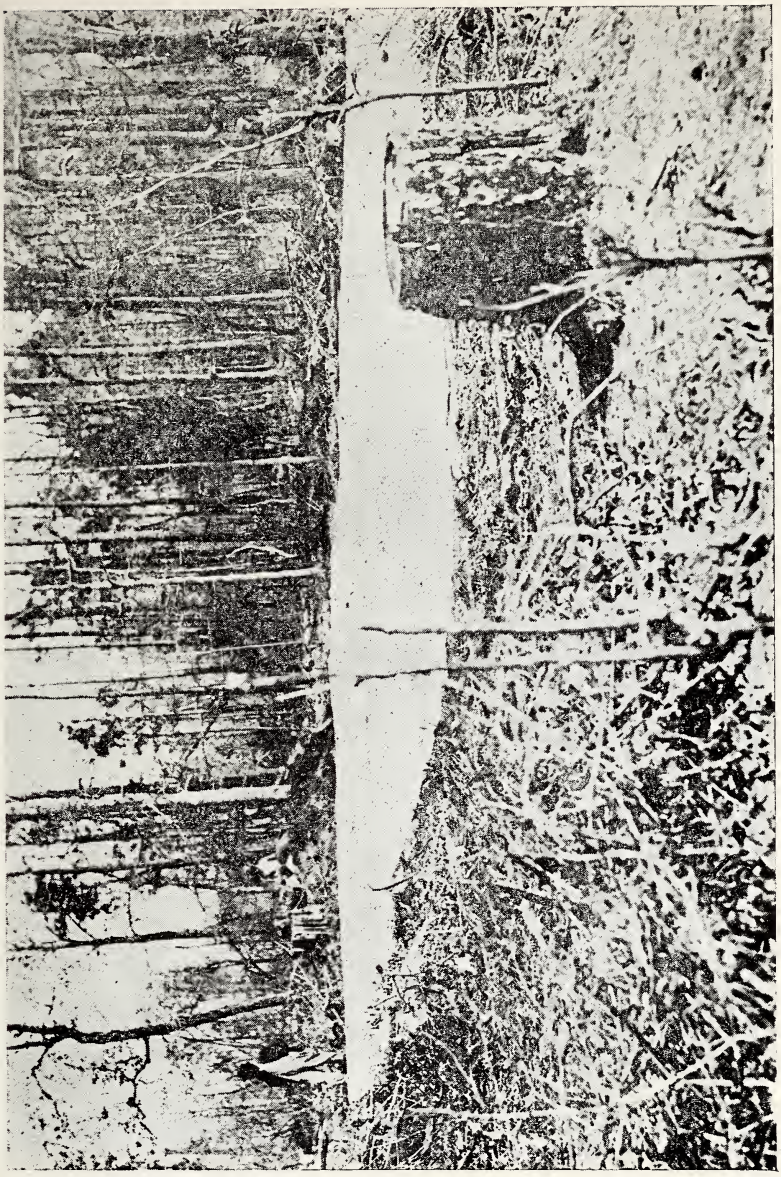

FIG. 24—The usual location for a tobacco plant bed, showing ideal hibernating places for Tobacco Flea Beetles. Such places should be cleaned up before the seed is sown. (See page 30.) (Original.)

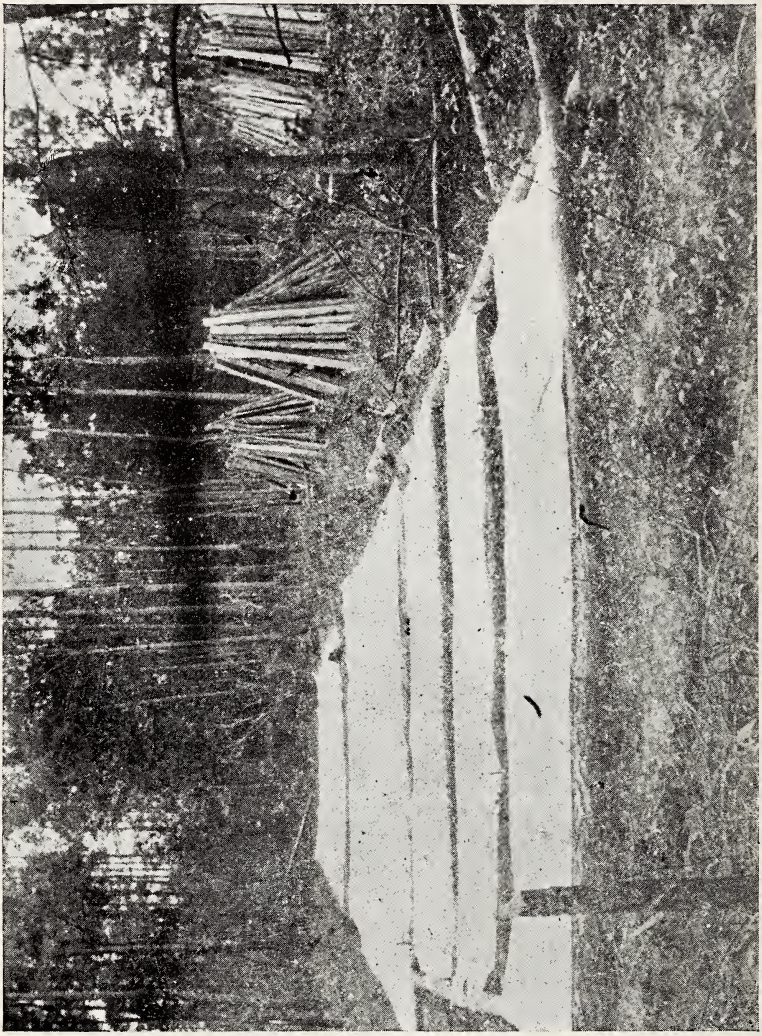

FIG. 25—The usual type of frame and cover. This cover offers no barrier to the Tobacco Flea Beetle. Contrast figure 22. (Original.)

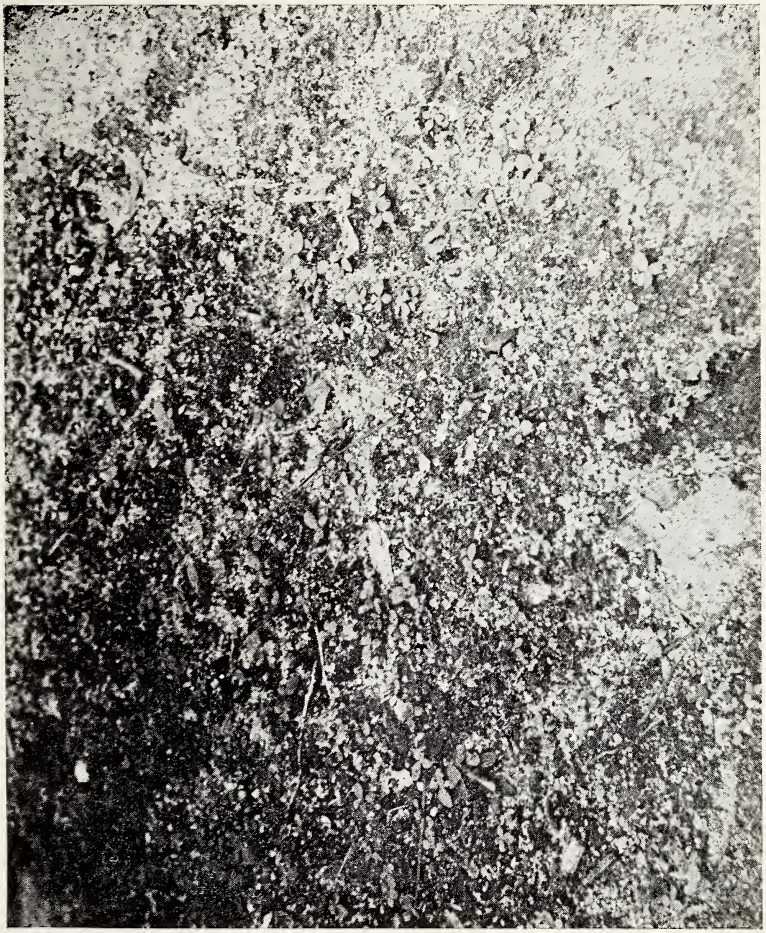

FIG. 26—Tobacco plants just coming up in the plant beds, showing the right time to make the first application of poison. The largest leaves are about the size of a dime. (Original.)

FIG. 27.—Tobacco plants in plant beds. Too late to make the first application of poison. The largest leaves are about the size of a silver dollar. (Original.)

the main supply of plants under any conditions, spray or dust these thoroughly once every week until through setting out the crop. (See page 37.)

5. Be certain to treat the bed with a heavy application of poison immediately after transplanting the last of the crop, plow up the old bed, destroying every tobacco plant left, and plant some crop, or better, cover with straw or saw-dust to prevent weeds growing and to catch all weed seed. Rake this off when ready to sow seed for the next crop. Never leave the old bed for a breeding place, as is shown in Fig. 30, as the beetles continue to breed throughout the season; larvae and pupae were found as late as the first week in October in this bed.

DUSTING AND SPRAYING THE PLANT BEDS

Since the results of the experiments show that nearly all of the tobacco flea-beetles gather on the tobacco beds in the early spring, an opportunity is presented to kill practically all of the overwintering beetles, thus greatly reducing the numbers to be found in the fields later on. It is doubtful if a better scheme could be devised for controlling this pest than the fact that they collect on the plant beds, as practically all of the beetles in the neighborhood are collected in a limited area which can be readily treated with an insecticide. With this in mind, a long series of experiments were carried on in dusting and spraying plant beds with arsenate of lead and arsenate of lime at different strengths. All of the mixtures checked the ravages of the tobacco flea-beetle, and in every case the plants on the treated beds were in much better condition at transplanting time than those on untreated beds close at hand.

As a result of these experiments it is recommended that the plant beds be sprayed with arsenate of lead (paste) at the rate of 1 pound to 10 gallons of water, or with arsenate of lead (powdered) or arsenate of lime at the rate of 1 pound to 20 gallons of water; or the plants may be dusted with powdered arsenate of lead or arsenate of lime mixed with fine sifted wood ashes at the rate of 1 pound of the poison to 4 pounds of the ashes.

Whether the farmer chooses to spray or dust his plants apparently makes no difference, as one method seems to be as effective as the other. The choice of methods will therefore depend upon the equipment available and the experience in spraying. It is much simpler and cheaper to dust the beds than to spray them. All that is required for dusting is that the poison be thoroughly mixed with the ashes at the rate mentioned above, and that the sack be made of cheese cloth or other thin material through which the mixture will sift slowly. It is absolutely necessary to mix the ashes and the poison thoroughly until the whole mass is light gray in color without any streaks or spots. This can readily be accomplished by placing the ashes and poison on a paper and mixing with a spoon or knife. The mixture should be dusted lightly and uniformly over the

whole bed, care being taken not to get too much of the mixture in one place.

The most convenient apparatus for spraying is what is known as a bucket pump with a lead of hose about 15 to 20 feet long and an extension rod about 3 or 4 feet long, provided with a disc nozzle.

The number of times it will be necessary to dust or spray the beds will depend upon a number of factors, the principal ones being the amount

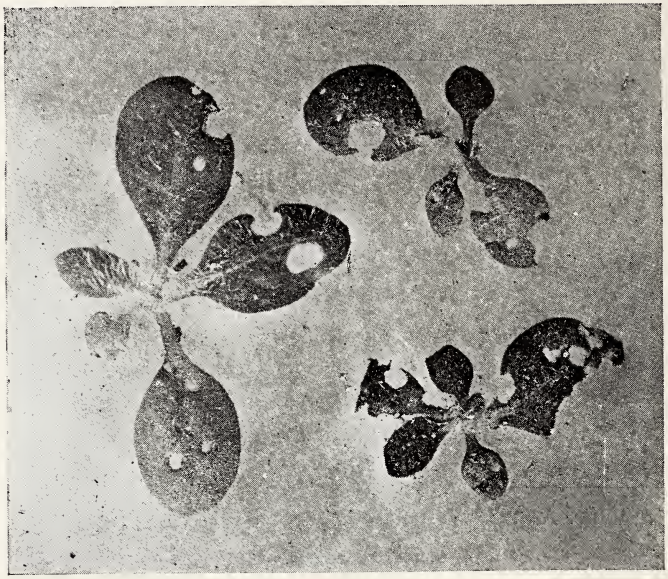

FIG. 28—Very young tobacco plants badly damaged by Tobacco Flea Beetle. (Original.)

of rain, as rain washes the poison from the leaves; and the rapid growth of the plants which offers fresh surfaces for the attacks of the beetles. The first application should be made just as soon as the plants are up (Fig. 26). The beds should then be watched closely, and as soon as small holes are noticed in the leaves, the beds should be treated again. This practice should be followed as long as the plants are in the beds.

DIPPING THE PLANTS AT TRANSPLANTING TIME

At transplanting time the farmer should provide a tub or other large vessel filled with arsenate of lead solution prepared by mixing arsenate of lead (1 pound paste or ½ pound powder) in 5 gallons of water. This mixture should be carefully prepared and kept thoroughly agitated by stirring frequently with a paddle. Then as the plants are pulled from the bed they should be laid out straight in small bundles. Each bundle should be picked up separately and the leaves only dipped into the arsenate of lead solution. The plants should be separated as much as

possible while they are in the solution, so that every leaf will receive a coating of the poison. As the plants are withdrawn they should be shaken slightly to remove the excess poison. Care must be taken not to shake them too violently or too much of the poison will be removed.

Fig. 29—Young tobacco plants badly damaged by Tobacco Flea Beetle. (After Metcalf, N. C. Dept. Agr.)

After a few bundles are dipped look at the first bundles and notice whether the leaves are completely and uniformly covered with a dry white powder. If large drops of water have collected here and there on the leaf it means that the plants should be shaken a little bit more as they are removed from the poison. The plants can be set almost as rapidly in this way as by the old method. And the additional protection from flea bugs is very valuable indeed, as they are usually very destructive at transplanting time, due to the fact that they have been forced to

FIG. 30—A plant bed where the weeds have been allowed to grow. This furnishes an excellent feeding and breeding place for Tobacco Flea Beetles, and permits them to spread to the fields which are usually near-by. (Original.)

leave the plant beds, and also to the fact that the plants receive a very severe check at this season of the year. This will also aid in checking the beetles that come from outside sources. This method, if properly used, will not injure the plants in any way, but will stimulate the growth at this critical period.

FIELD AND CULTURAL METHODS OF CONTROL

1. If beetles were present the previous season in the same field or near by, burn over the surrounding hibernating ground for a good safe distance. Do this before the seed is sown.

2. Break the land as early as possible; do not let volunteer plants come up from sucker seed, as they are likely to do around stumps and along the edges of the field.

3. Destroy every host plant (weeds, etc.) of the Solanaceous family (Fig. 5) in and around the fields. Do this persistently from early till late every season, until these are exterminated.

4. Set out a part of the crop, an acre or so, as early as possible, say ten or twelve days earlier than the main crop, at the most advantageous places for the beetles to collect as they come from hibernation. Dip these plants before transplanting (page 38) and spray or dust them thoroughly about twice before the main crop is put out. This will destroy the greater percentage of those that come from hibernation, and these are the most important ones to destroy, because they are the parents of all later generations.

5. Try to get out all of the main crops within two weeks. Late transplanted tobacco is usually thin and light, and the beetles will do great damage to all of the leaves from bottom to top.

6. Select seed from early maturing stalks only. Develop an early maturing variety. In selecting seed, in fertilization, and cultivation, carefully look out for earliness and uniformity in ripening. Late tobacco is nearly always badly damaged.

7. Have your tobacco seed thoroughly cleaned. The State Department of Agriculture, Raleigh, North Carolina, will clean a pound of tobacco seed for any farmer free of charge. For amounts of more than a pound a slight charge will be made. Cleaned seed means more uniform and better plants in the tobacco bed, hence better plants at transplanting time, thus insuring much more uniform plants in the field.

8. Practice frequent and thorough cultivation. This destroys large numbers of eggs, larvae, and pupae, all of which occur in the ground, at or near the surface. Keep a dry mulch around the base of the plants at all times. This gives less favorable conditions for the incubation of the eggs, and for the development of the larvae and the pupae.

9. Prime off the bottom leaves that lie on the ground. This should be done before the last cultivations. Nearly all larvae and pupae taken in the field were found under leaves which were on or near the ground.

FIG. 31.—Suckers growing up in the field. These suckers should have been destroyed after the tobacco was harvested. (See page 44.) (Original.)

Fig. 32—A near view of tobacco suckers, showing how they have been riddled by Tobacco Flea Beetles. (Original.)

These leaves offered shade and retained moisture in the soil which were favorable for the deposition and hatching of eggs, and the development of larvae and pupae.

10. Do not interplant any crop like cowpeas for instance, between the tobacco hills, or broadcast peas in the field, as this makes the best condition for the feeding of the beetles after the tobacco crop is harvested. In addition these plants shade the ground offering the best conditions for the development of the last generations of beetles, thus insuring that there will be a large number of beetles going into hibernation.

11. Remove all stumps, bushes and hedgerows in and around the tobacco field, as leaves blow against these and offer the best hibernating places.

12. It is important to work up community coöperation in all of these methods for the best results.

DESTRUCTION OF ALL SUCKERS AFTER THE CROP IS HOUSED

The destruction of the suckers which grow up in the field after the tobacco crop is harvested is one of the cheapest and easiest methods of controlling the tobacco flea-beetle, as well as all other kinds of tobacco insects. If the tobacco grower will visit his field early in the fall and examine the suckers he would be impressed with the large numbers of tobacco flea-beetles, horn worms, bud worms, and all kinds of tobacco insects to be found in the field at this time. In other words the suckers simply afford an abundance of food for these destructive pests, from the time the crop is harvested until the pests are driven into winter quarters by killing frosts. If the tobacco farmer were to try and devise some method to insure an abundant supply of destructive pests for his next year's crop, it is doubtful if he could devise any better scheme than allowing the suckers to grow up in the field. The principal objection that is raised against this method is that the farmer is too busy to do this work at this season of the year. The authors of the bulletin appreciate the validity of this argument, as it is doubtful if there is a busier season on a tobacco farm than this season of harvesting, curing and marketing of the crop. To repay for the extra labor involved, the following advantages are urged: (1) That this will decrease the number of insect pests in the tobacco fields the following season to such an extent that the crop will be raised easier and cheaper enough to more than repay for the extra labor involved; (2) and that the suckers should be cut just at this season of the year, in order to enable the tobacco farmer to plant some cover crop. The advantages of planting a cover crop are so many and are generally so well understood that we need not discuss them further here.

The earlier these stalks are cut the better, as all of our experiments

Fig. 33—Leaves from suckers in the field completely riddled by Tobacco Flea Beetles. (Original.)

JUNE, 1919 BULLETIN 241

SOYBEANS AND COWPEAS

FOR

NORTH CAROLINA

V. R. HERMAN

DIVISION OF AGRONOMY

COWPEAS SOYBEANS

NORTH CAROLINA
AGRICULTURAL EXPERIMENT STATION
CONDUCTED JOINTLY BY THE
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AND THE
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CONTENTS

SOYBEANS AND COWPEAS FOR NORTH CAROLINA

BY

V. R. Herman, *Assistant Agronomist*

COWPEAS FOR NORTH CAROLINA

From best accounts the cowpea is a native of Central Africa. Over a large portion of that country, there can be found at the present time a small, wild plant closely resembling the cultivated forms of this country. The cowpea has been grown for human food in Asia, Africa, and in Europe along the Mediterranean, for many centuries. It was introduced into Carolina about 1775, probably coming from the West Indies.

The climatic requirements of the cowpea make it chiefly a southern crop. It stands heat well, but is very sensitive to cold, being killed by the first frost in the fall. It will grow on any well drained soil; but, like most other legumes, does best on soils that have received a liberal application of lime, or that are naturally sweet. The plant tolerates a certain amount of shade which adapts it for growth with corn, or in orchards. This adaptability to so many conditions, and uses, makes the cowpea a very important crop in North Carolina. On account of its quick, luxuriant growth and high feeding value, it is a good hay crop, an efficient soil builder, a human food of importance and a splendid temporary pasture crop. Although grown in this State for nearly a century and a half, it will not be fully appreciated until after having been used more generally as a soil builder.

Cowpeas for Hay

Cowpeas are grown for hay more than for any other one purpose. Heavy yields, quick growth, and a high percentage of several important nutrients, make the crop ideal for this purpose.

On account of its quick growth, the cowpea can be planted after a small grain crop is harvested. A crop of cowpea hay can be grown and harvested in time to use the land for wheat, rye, clover, or a winter cover crop. In this way a crop of good hay is grown, leaving the soil in better physical condition than when left idle to grow weeds.

In food value, cowpea hay ranks very high, being practically equal to wheat bran, which is recognized as one of the standard concentrate feeds.

Compared with other hays, the cowpea is one of the most palatable when cured properly, and ranks among the best in feeding value. In Table I is given the protein, carbohydrate, and fat content of some of the most commonly fed hays.

(1) The work reported on in this bulletin was conducted by the Division of Agronomy in coöperation with the office of Forage Crop Investigations of the U. S. Department of Agriculture.

TABLE I

COMPARATIVE FEEDING VALUE OF HAYS

	Water	Ash	Protein	Carbo-hydrates	Fats	Fiber
Cowpea hay	10.7	7.5	16.6	42.2	2.2	20.1
Soybean hay	11.3	7.2	15.4	38.4	5.2	22.3
Alfalfa hay	8.4	7.4	14.3	42.7	2.2	25.0
Red clover hay	15.3	6.2	12.3	31.1	3.3	24.8
Oat hay	15.0	5.2	9.3	39.0	2.3	29.2
Timothy hay	13.2	4.4	5.9	45.0	2.5	27.2
Johnson grass hay	10.2	6.1	7.2	45.9	2.1	28.5
Corn stover hay	40.5	3.4	3.8	31.5	1.1	19.7

The above analyses represent pounds of each material in one hundred pounds of hay.

A study of this table shows that cowpea hay contains the greatest amount of protein, exceeding alfalfa hay by 2.3 per cent, Red Clover by 4.3 per cent, and oat hay by 7.3 per cent. Home-grown cowpea hay contains nearly three times the amount of protein found in Timothy hay, and over four times the amount found in corn stover. In carbohydrates, cowpea hay is surpassed by Timothy 2.8 per cent, by Johnson Grass, 3.7 per cent, and by alfalfa hay only .5 per cent. With the exception of soybean hay, cowpea hay compares very favorably with other commonly fed hays in fat content.

In yield of hay per acre, the cowpea compares very favorably with the other commonly grown hays. In yield of actual food per acre, it ranks very high. Cowpeas have an advantage over most hay crops in that they occupy the land but a short time through the summer.

The actual yield of cowpea hay per acre will depend, to a large extent, upon condition and fertility of the soil, fertilizer applied, cultivation, and amount of moisture. Under average conditions 1½ to 2 tons per acre is a fair yield, though much larger yields are reported. On very poor soil, peas may not yield a ton per acre, but if planted on a fairly fertile, well prepared soil, they should make at least 2 tons per acre.

Usually, cowpeas are considered hard to cure for hay, but when properly handled this should not be the case. The old system of cutting the vines and allowing them to cure on the ground has proven very unsatisfactory. When this method is used, most of the leaves are lost, and often the entire crop is damaged or destroyed by rain.

Curing Cowpea Hay

Experience has shown that the most satisfactory way to harvest cowpea hay is to cut after the dew is off in the morning, and allow the vines to lie in the sun for a few hours until the leaves and plants begin to wilt. Toward evening, before the leaves become dry enough to fall or become brittle, the vines are raked in rolls. The hay is then ready to be placed on ventilated stacks. A very satisfactory and cheap stack can be made by putting a pole in the ground and nailing several series of cross

pieces on it. Care should be used in shaping the stacks so they will shed rain. In a few weeks a stack of this kind will cure the hay perfectly. Where it is not possible to cure in ventilated stacks, the hay may be raked into small cocks in the field. By turning the hay at intervals it will be ready for storage in a few days. In dry weather this method is very satisfactory, but it is risky to cure cowpea hay on the ground.

Cowpeas should be cut for hay when the first pods begin to ripen, and just before the leaves begin to fall, for at this stage the plant contains its maximum amount of food. When cut much earlier, the vines have not gained their maximum growth, and if cut much later the leaves have fallen.

Cowpeas for Seed

Cowpeas are not grown very extensively for seed, due to the expense of harvesting and low yields secured. The yield of seed, like that of hay, will depend to a large extent upon weather conditions, soil fertility, and planting methods. If planted on a soil rich in nitrogen, cowpeas will make a heavy growth of vine, but little fruit. Plantings made about June 1 will usually make a greater proportion of seed to vine, than when planted earlier. When planted in rows they will yield two to three times the amount of seed produced when planted broadcast. In an average of three years test on the Coastal Plain Branch Station near Rocky Mount, peas broadcasted yielded 2.55 bushels per acre, while those cultivated in two-foot rows produced 6.8 bushels per acre. In eastern and Piedmont North Carolina, 10 bushels per acre is a fair yield. In the cooler mountain section, they will hardly yield so well.

There are several methods of harvesting the seed. They can be harvested by hand-picking and thrashing with a flail, where only a few bushels are grown. When the pods are thoroughly dry, this is not a very hard task. They may also be thrashed on a small pea or bean thrasher, of which there are several makes now on the market. One advantage of the hand-picking is that the vines are left on the soil. Large quantities, however, may be most economically harvested by allowing the pods to ripen on the vine, after which the crop is handled as for hay. When harvested in this way they may be thrashed on a special pea and bean thrasher, an ordinary grain separator, or a corn shredder. To successfully thresh on a grain separator, or a corn shredder, the gearings should be changed so that the cylinder will run at about half speed, while other parts of the machine run at normal speed. If the cowpeas are cut and thrashed from the vine, it is best to cut when three-fourths of the pods are ripe, and before the first pods are shattered or damaged.

Cowpeas for Temporary Pasture

As a pasture crop, cowpeas are used chiefly for hogs. Its value for this purpose will depend upon the amount of growth and seed produced. Under most North Carolina conditions, the cowpea is inferior to soybeans as a grazing crop. The Kentucky Experiment Station, comparing

cowpeas and soybeans for hog pasture, found that when corn was fed at the rate of two per cent of live weight, the pork from cowpea pasture cost $17.19 more per hundred pounds than that from the soybean pasture.

In a three year comparison of cowpeas and soybeans for hay and seed production, the Mammoth Yellow soybean produced 23.92 bushels of seed and 3,028 pounds of hay per acre, while the Groit cowpea produced only 11.6 bushels of seed and 1,608 pounds of hay. This comparison was made with the leading variety of the two crops planted in forty-inch rows. Both the cowpea and soybean yield better for seed and hay when planted in rows, but the cowpea is much better adapted to broadcast planting than the soybean, on account of its ability to more successfully compete with weeds and grasses. For this reason, cowpeas should be used when it is necessary to provide pasturage by planting broadcast.

Cowpeas for Soil Improvement.

Every farmer should have as his aim the permanent improvement of his soil. Soil improvement is an investment which may be temporary or permanent. The income from such an investment depends upon the thoroughness and economy with which it is made. Temporary improvement may come from the use of commercial fertilizer, but in permanent improvement some form of organic matter must be used. Since very few farms of the State produce sufficient stable manure to furnish this organic matter, it is necessary to supply it by the growth of legumes.

Leguminous plants such as cowpeas, soybeans, clover and vetch are more valuable for soil improvement than plants not belonging to this group, because these legumes are able to gather nitrogen from the air, and use it for plant growth. Since the nitrogen is taken from the air that circulates through the soil, the deeper and better prepared soils will aid the development of a greater root system, a larger plant and thus furnish a greater quantity of organic matter to be stored in the soil. The cowpea is without doubt the best summer legume used for soil improvement. Its quick growth and large deep growing root system makes it ideal for this purpose.

The actual amount of soil improvement secured from growing cowpeas will depend upon the disposition made of the vine. If the vine is removed for hay, the cowpea, or any other legume ceases to be a soil improving crop, since more fertility is being taken away than is left. On the other hand, if the vine is left on the soil, the amount of improvement is dependent upon the amount of growth turned under.

A ton of cowpea hay contains 53.2 pounds of nitrogen, 13.2 pounds of phosphoric acid, and 47.2 pounds of potash. Pricing nitrogen at 35 cents per pound, phosphoric acid at 6 cents, and potash at 30 cents, a ton of cowpeas would contain $33.57 worth of fertilizing materials. Of these materials, the phosphoric acid and potash amounting to $14.95

are taken directly from the soil. The nitrogen which amounts to $18.62 is taken, about ¼ from the soil and ¾ from the air. Thus, for every ton of cowpea hay removed, $19.61 worth of fertilizing materials are taken from the soil.

Considering only the fertilizing materials returned to the soil, the turning under of cowpeas would not be a profitable practice. More important than the plant food is the humus or organic matter supplied. Humus supplied in this way makes it possible to increase the depth of soil, thereby giving it a greater water holding capacity, and furnishing a greater feeding area for plants. Humus also improves the physical condition of soils, making stiff clay soils more open and sandy soils more compact.

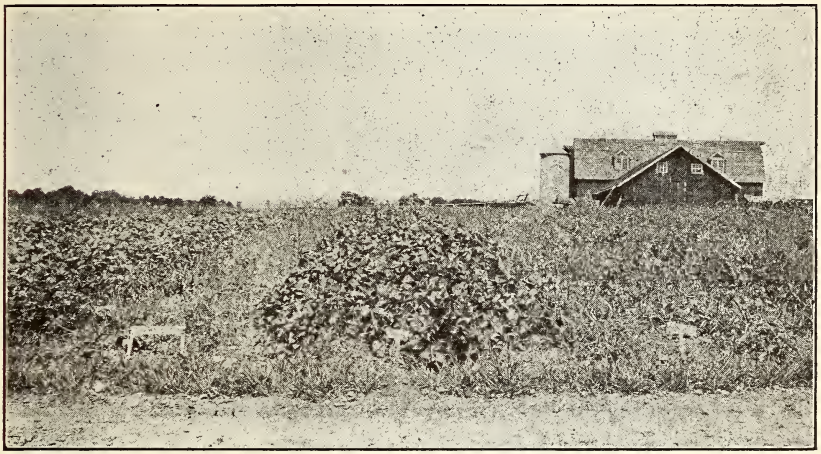

Fig. 1. Brown Coffee, Iron, and Black Cowpeas, showing difference in resistance to wilt.

It is advisable to thoroughly cut cowpeas with a disk harrow several days before they are turned. This not only thoroughly mixes the vines and soil, but puts the soil in much better condition. Particularly is the disking important when the cowpeas are to be followed immediately with small grain.

Cowpeas in Rotation

The cowpea has justly gained an important place in most of our carefully planned rotations. Particularly is this true in piedmont and western Carolina, where small grains are grown extensively. In these sections, wheat, oats, and rye are usually harvested from June 1 to 15, leaving enough time to grow a crop of peas for soil improvement or for hay. This not only makes a profitable crop, but keeps a desirable crop where a troublesome weed might be growing. Cowpeas fit in well as a catch crop between small grain crops and other winter cover crops.

Cowpea Culture

Probably no other crop so widely grown in North Carolina is planted under such varied conditions, or given so little attention in soil preparation and cultivation as the cowpea. Yet, in spite of these conditions, probably no other crop is expected to so successfully overcome adverse conditions and produce a heavy crop of vines and seed. To most growers, the cowpea is looked upon as a poor land crop. Soil too infertile or too poorly prepared to grow other crops is usually planted in cowpeas. The cowpea will do its part toward building up infertile or run down soil, but, if maximum results are expected better preparation, cultivation and fertilization must be given.

TABLE II

COWPEA CULTURE EXPERIMENTS

COASTAL PLAIN BRANCH STATION, ROCKY MOUNT, N. C.

Variety.	Method of Seeding.	Yield Seed Bu. per A.	Yield hay, lbs. per A.	Per cent of weeds in hay.
New Era	Broadcast	2.55	1630	42.30
New Era	24 in. row	6.80	1080	0
New Era	40 in. row	6.28	1003	0
Brabham	Broadcast	4.72	2197	36.67
Brabham	24 in. row	12.55	2089	0
Brabham	40 in. row	8.56	1573	0

TABLE III

COWPEA CULTURE EXPERIMENTS

MOUNTAIN BRANCH STATION, SWANNANOA, N. C.

Variety.	Method of Seeding.	Yield Seed Bu. per A.	Yield hay, lbs. per A.	Per cent of weeds in hay.
New Era	Broadcast	.39	4190	95.00
New Era	24 in. row	1.67	1940	0
New Era	40 in. row	5.01	1626	0
Brabham	Broadcast	.21	5780	87.00
Brabham	24 in. row	.71	4635	0
Brabham	40 in. row	2.17	3375	0

Cowpeas are not limited to any particular type of soil. They will grow well on soil ranging from a stiff clay to a light sand. Good drainage and freedom from acidity or sourness is of greater importance than type of soil.

Methods of Planting

There are several methods of planting cowpeas; the method depending very largely upon what the peas are to be used for. When grown for seed or pasture, they should be planted in rows. For hay production they may be planted in rows, broadcasted, or seeded with a grain drill. When grown for soil improvement they may be sown either broadcast or in other crops like corn.

Results of this station secured on the Coastal Plain and Mountain Branch Stations show that peas planted in rows will yield twice as much seed and equally as much hay as when broadcasted. (See Table II and III.) The tables contain the average results of three tests in which the broadcasted plats were planted at the rate of 75 pounds, the two foot rows at the rate of 45 and the forty inch rows received 30 pounds per acre. The quality of hay from row plantings is much higher, since it contains much less weeds and grass. At the Mountain Branch Station

Fig. 2. Cowpeas Broadcasted in Corn for Soil Improvement.

the hay from the broadcast plats contained 87 per cent weeds, and that at the Coastal Plain Station contained 36.67 per cent weeds.

When planted in rows, the soil should be thoroughly prepared. A good seed bed furnishes better conditions for germination and require less cultivation afterwards. On heavy clay soils, peas should never be planted when the soil is wet. This promotes packing and baking and a

TABLE IV

Cowpea Culture Experiment

Experiment Station Farm, West Raleigh, N. C.
1915, 1916, 1917

Variety.	Distance between plants in inchs.	Distance between rows in inches	Yield seed Bu. per Acre.
New Era	3	40	13.83
New Era	6	40	14.27
New Era	12	40	12.11
Groit	3	40	15.46
Groit	6	40	21.60
Groit	12	40	20.83
Brabham	3	40	10.99
Brabham	6	40	13.28
Brabham	12	40	12.59
Wonderful	3	40	6.53
Wonderful	6	40	8.66
Wonderful	12	40	11.31

TABLE V

RATE OF SEEDNG COWPEAS

MOUNTAIN BRANCH STATION, SWANNANOA, N. C.

Variety.	Rate seeding lbs. per A.	Yield seed bu. per A.	Yield hay lbs. per A.	Per cent of hay weeds.
Brabham	30 Broadcast	.00	6836	90.00
Brabham	60 Broadcast	.09	6006	82.50
Brabham	90 Broadcast	.50	8973	92.50
Brabham	120 Broadcast	.17	7100	90.00

TABLE VI

RATE OF SEEDING COWPEAS

COASTAL PLAIN BRANCH STATION, ROCKY MOUNT, N. C.

Variety.	Rate seeding lbs. per A.	Yield seed bu. per A.	Yield hay lbs. per A.	Per cent of hay weeds.
Brabham	30 Broadcast	2.84	2434	68.00
Brabham	60 Broadcast	4.78	2200	27.70
Brabham	90 Broadcast	4.83	2633	15.00
Brabham	120 Broadcast	5.22	2773	12.50

crust is formed through which the young plants cannot grow. Peas may be planted in rows two to three feet apart, though the three foot distance is best for seed production. The planting may be done either with machinery or by hand. A planter is better, since it gives a more regular stand and takes less seed. The seed may be drilled in the row, or planted in hills. Culture experiments, conducted on the Station Farm, showed that a distance of six inches between plants in three foot rows has given a greater yield of seed, than spacings of three or twelve inches. The average results of these comparisons for three years are given in Table IV. When grown for hay, better results have been secured from plantings of 40 to 50 pounds of seed per acre in two-foot rows. The yield of hay is greater from the thicker plantings and the plants made a more upright growth which is easier to harvest.

Cowpeas planted about June 1, usually require less cultivation because the plants grow off rapidly soon covering the middle, thus preventing the growth of weeds and grasses. When a good seed bed is prepared, and cultivation is started in time, hoe work is unnecessary. Broadcast planting of peas is usually done after small grain are harvested. The seed bed for this purpose may be prepared with a turn plow, or with a heavy disk harrow, the deeper breaking being preferable. In case small grain is to follow peas, the breaking should be fairly deep, as this would lessen the cost of preparation in the fall. Before broadcasting peas, a good seed bed should be prepared. Unless this is done, the yield of hay is likely to be small, and the quality poor on account of the large growth of objectionable weeds. This can be remedied to some extent by thick planting. For broadcasting, 90-100 pounds of seed per acre is best on most soils (See Tables V and VI). Plantings made in other crops like corn may be alternated with rows of corn, planted in the rows with corn, or broadcasted at the last cultivation. When alternate rows of corn and

TABLE VII

Date of Seeding Cowpeas

COASTAL PLAIN BRANCH STATION, ROCKY MOUNT, N. C.

Variety.	Date seeding.	Bu. seed per acre.	lbs. hay per acre.
Groit	May 1	12.75	1490
Groit	May 15	16.00	1880
Groit	June 1	17.09	2180
Groit	June 15	14.33	2330
Groit	July 1	15.36	2500
Groit	July 15	13.34	1685

TABLE VIII

Date of Seeding Cowpeas

MOUNTAIN BRANCH STATION, SWANNANOA, N. C.

Variety.	Date seeding.	Bu. seed per acre.	lbs. hay per acre.
Groit	May 1	4.21	2665
Groit	May 15	6.08	2845
Groit	June 1	5.50	4060
Groit	June 15	3.79	3661

peas are planted, the peas should be put in at the second cultivation of the corn. In this way, a fair yield of seed is usually produced. Broadcast plantings made in the corn should be sown as early as possible but not so early as to interfere with the cultivation of the corn. In cases where the corn has made a very dense growth, the peas will not do much on account of the shading and lack of moisture.

Fertilizer for Cowpeas

A ton of cowpea hay contains 53.2 pounds of nitrogen, 13.2 pounds of phosphorous, and 47.2 pounds of potash. About three-fourths of the nitrogen is taken from the air, if the soil is inoculated, but phosphorous and potash are either supplied in fertilizer, or removed from the soil. If we are to keep our soils to a high state of fertility, it is best to apply at least a part of this as fertilizer. An application of 150 to 200 pounds per acre of a fertilizer analyzing 8 per cent phosphorous, 1 to 2 per cent nitrogen, and 2 per cent potash is sufficient for eastern Carolina soils. In Piedmont and western Carolina, the potash may be left out. Cowpeas are strictly lime loving plants. The nitrogen gathering bacteria that live on the roots cannot live in an acid soil. Lime should be applied before the cowpeas are planted.

Inoculation

The majority of North Carolina soils are already inoculated with the nitrogen fixing bacteria for cowpeas. Where cowpeas have never been grown, or at least not in recent years, it might be well to inoculate the soil before planting. This can be done with the commercial culture, or by the use of soil on which cowpeas have been grown successfully.

Time to Plant

In eastern Carolina, peas may be planted from May 1 to July 15 and make a crop of either hay or seed. Results of tests on the dates of seeding conducted by this Station have shown May 15 to June 15 the best date to plant anywhere in the State (See Tables VII and VIII).

Diseases of Cowpeas

The chief diseases of the cowpea are wilt and root knot, both of which are more prevalent in Lower Piedmont and eastern Carolina. Cowpea wilt is strictly a soil disease and attacks the plant through its roots. The first sign of this disease is shown by the yellowing of the lower leaves. This is usually followed by the loss of leaves and death of the plant. The plant may be attacked at any stage of growth, though it usually becomes apparent about the time of blooming. In the early stages of the disease the leaves turn yellow and fall or the plants show signs of wilting. When the stems of such plants are cut near the ground one will find a brown or black colored ring just under the bark. In advance stages of the disease the lower portion of the stems may be dead. The killing is due to the closing up of the small tubes, which conduct the water and food to the upper stems and leaves.

The only safe method of controlling this disease is to plant resistant varieties, and to rotate with crops which are not troubled with it. Iron, Monetta and Brabham compeas are resistant to the disease, Groit and Whippoorwill are seldom damaged, while Early Bluff, Red Ripper, Taylor and Black are usually badly damaged. In the sandy, wilt infested soils, Brabham has proven to be an excellent variety for seed and hay.

Root Knot is caused by a small worm, known as a nematode, which bores into the plant roots causing enlargement of the roots. These little nematodes increase quickly, spreading to the whole root system, soon killing the plant or preventing proper development. This disease is confined to sandy soils, and can be controlled to some extent by growing Brabham, Iron, and Monetta cowpeas.

Insect Enemies of Peas

One of the chief insect enemies of the cowpea is the cowpea weevil, which feeds upon the stored seed. This insect begins its work by laying eggs on the seeds before harvest. When harvested and stored, the weevils multiply very fast and are very destructive. Carbon bisulphide fumigation has been used to some extent for controlling this insect, but its use is not very practical on the farm. *Metcalf of this Station has found an application of air slaked lime very practical for protecting stored cowpeas from weevil damage. According to his experiments, small lots of thrashed peas, up to three bushels, should be mixed with an equal weight of slaked lime. In lots up to 25 bushels, one part of lime and two of peas has been found effective. Quantities greater than 25 bushels

*Journal of Economic Entomology, February, 1917.

may be protected by mixing one part of lime with eight of peas, and then covering the peas with a layer of lime one-half inch thick. If the peas are kept dry the lime will not injure the germination, and can be sifted out before planting, if desired. The lime can easily be washed off in case the peas are to be used for feed or for human consumption.

VARIETY TEST

The Station began the testing of cowpea and soybean varieties in the spring of 1915 to determine which of these important leguminous crops was more profitable to grow, which best fitted into our present cropping system, and which of the existing varieties gave the largest yields of both seed and hay in different sections of the State.

Fig. 3. Cowpea Variety Test, Experiment Station Farm.

Variety comparisons will be shown in separate tables of cowpeas and soybeans. The variety testing was done on the Mountain Branch Station, which represents the mountain section of the State; the Piedmont Branch Station, representing the northeastern section, and the Trucking Branch Station in the southeastern or trucking section of the State.

To be of value, the soil upon which a variety test is conducted should be absolutely uniform for all the varieties. *Each variety should be fertilized, cultivated, and harvested in the same way.* All hay weights should be calculated to the same amount of moisture. These conditions have been conformed to as near as possible on all farms.

On all farms 1-10 of an acre was seeded to each variety; one-half being cut for hay, and the other left to mature for seed. Each variety was planted in rows 40 inches apart, the seed being drilled in the row. Each plot was fertilized at the rate of 150 pounds per acre of a fertilizer analyzing 8 per cent phosphoric acid and 2 per cent nitrogen. Seeds for the test on all farms were grown on the Experiment Station Farm at West Raleigh, being hand-picked each year to keep varieties pure.

TABLE IX

COWPEA VARIETIES

MOUNTAIN BRANCH STATION, SWANNANOA, N. C.
1915, 1917 and 1918

FOR SEED				FOR HAY			
Variety	Per Cent Stand	Number of Days to Mature Seed	Yield of Seed Per Acre in Bushels	Variety	Per Cent Stand	Number of Days to Mature Hay	Yield of Hay Per Acre, Pounds
Early Red	95	138	6.85	Groit	87	124	4010
Taylor	80	148	5.89	Monetta	95	124	3460
New Era	91	138	5.31	Iron	91	124	3380
Groit	87	138	5.06	Black	74	124	3110
Monetta	95	159	4.29	Red Ripper	87	124	3080
Brabham	95	159	4.24	Whippoorwill	72	124	2900
Iron	91	159	4.22	Taylor	80	124	2700
Red Ripper	87	148	4.17	Black Unknown	79	124	2500
Whippoorwill	72	149	3.67	New Era	91	124	2440
Two-crop Clay	89	128	2.50	Early Red	95	121	2080
Black	74	149	1.60	Brabham	95	124	1880
Black Unknown	79	149	.75	Two-crop Clay	89	121	1460
Wonderful	64	Killed by frost		Wonderful	64	157	760

COWPEA VARIETIES

Mountain Branch Station

The Mountain Branch Station is located in the Swannanoa valley, eleven miles east of Asheville. The farm has an elevation of 2,400 feet above sea level. The soil type upon which the test was conducted is Toxaway loam.

The test began in 1915, and continued throughout 1918. In 1916, the varieties were destroyed by a flood. In Table IX is given the standing of different varieties for seed and hay production. Thirteen varieties were used throughout the test. Early Red, a medium early semi-trailing red seed variety, leads the test with 6.87 bushels of seed per acre. Taylor, a trailing variety, with a yield of 5.89 bushels; New Era, and Groit, two bunch varieties, yielding 5.31 and 5.06 bushels per acre, rank second, third and fourth. Whippoorwill, the variety most grown in North Carolina, stands near the bottom of the list. Wonderful, one of the leading hay varieties for the Piedmont section, failed to produce seed, due to its long growing season.

The varieties are also compared for hay yields in Table IX. According to these yields of hay, the Groit, Monetta, Iron and Black are the best varieties for hay production in this section. Early Red and Taylor, two of the leading varieties for seed production, rank low in the test for hay. There is a difference of 3,250 pounds of hay per acre between Groit, the leading variety, and Wonderful, the poorest. Its high yield of seed and hay, together with its bunch habit of growth, makes the Groit probably the best variety of cowpeas for this section. Early Red, Taylor and Monetta are also good varieties.

Catjang and Early Buff were included in the test for one year, but were discarded because of poor yields of both seed and hay. Iron & Warren, a new variety in the 1918 test, made a good showing, but was not so good as Groit.

PIEDMONT BRANCH STATION

The Piedmont Branch Station is located about two miles northwest of Statesville, in the upper portion of the piedmont section. The variety experiments were conducted upon Cecil Clay soil, in rotation with corn, oats and cotton. On all of these plats, acid phosphate was applied at the rate of 150 pounds per acre. Thirteen varieties were used in the tests during four years. The average yields of hay and seed for these varieties are given in Table X.

These results show a range in yield from 12.50 bushels per acre for Groit to 4.29 bushels per acre for Iron, a difference of 8.21 bushels per acre, the Groit yielding nearly three times more seed than Iron. For seed production in this section the Groit, Early Red, New Era, and Two Crop Clay have yielded best. In 1915 the Wonderful cowpea made a fine crop of seed, but in 1917 and 1918 it failed to set fruit at all.

TABLE X

COWPEA VARIETIES

PIEDMONT BRANCH STATION, STATESVILLE, N. C.
1915, 1916, 1917 and 1918

For Seed				For Hay			
Variety	Per Cent Stand	Number of Days to Mature Seed	Yield of Seed Per Acre in Bushels	Variety	Per Cent Stand	Number of Days to Mature Hay	Yield of Hay Per Acre, Pounds
Groit	93	104	12.50	Monetta	96	106	3057
Early Red	88	104	12.38	Wonderful	90	121	2773
New Era	91	104	12.23	Black	93	91	2709
Two-crop Clay	88	102	11.89	Iron	95	106	2637
Whippoorwill	91	104	11.88	Brabham	97	106	2616
Black Unknown	94	102	11.58	Red Ripper	94	97	2538
Red Ripper	94	108	11.42	Groit	93	89	2482
Black	93	105	10.31	Early Red	88	89	2192
Taylor	89	112	8.39	Black Unknown	94	98	2173
Monetta	96	118	5.59	Whippoorwill	91	96	2144
Brabham	97	119	4.92	New Era	91	89	1932
Wonderful	90	140	4.88	Taylor	89	92	1828
Iron	95	118	4.29	Two-crop Clay	88	89	1810

Table X also contains the results for hay yields. Here there is a range in yield from 3,057 pounds per acre for Monetta, to 1,810 for Two Crop Clay, a difference of 1,247 pounds of hay per acre. Monetta, Wonderful, Black, and Iron are the leading varieties for hay production. It will be noted that the leading seed varieties rank rather low in the test for hay. Groit, the leading seed variety, ranks seventh, with 575 pounds of hay per acre less than Monetta, though the feeding value of Groit hay is much higher, due to its larger yield of seed.

EXPERIMENT STATION FARM

The Experiment Station Farm is located about two miles west of Raleigh, near the border between the piedmont and coastal plain sections. The variety experiments on this farm were conducted on Cecil Sandy Loam soil.

Thirteen varieties have been compared for seed and hay yields during the past four years. The four year average yield for each variety is given in Table XI. In yield of seed per acre, the varieties range between 17.26 bushels per acre and 4.35 bushels per acre, a difference of 12.91 bushels. Groit, Early Red, Whippoorwill and New Era are the four leading varieties for this section.

In the comparison of varieties for yield of hay, the Wonderful cowpea leads, with a yield of 3,767 pounds per acre. Wonderful, Monetta, Black Unknown, and Groit are the four leading varieties for hay. For the combination yield of seed and hay, Groit and Whippoorwill are excellent varieties. For hay or soil improvement alone, Wonderful and Monetta are good. The Iron & Warren cowpea, which was included in these tests during 1917 and 1918 is a good variety, but is hardly equal to Groit for the production of hay or seed.

COASTAL PLAIN BRANCH STATION

The Coastal Plain Branch Station is located seven miles southeast of Rocky Mount. The prevailing soil type there is the Norfolk Sandy Loam. Twelve varieties have been compared on this farm during the past four years. The average yields of seed and hay are given for each of these varieties in Table XII. According to these results, Groit, Whippoorwill, Brabham, and Early Red are the best seed producing varieties in this section. In the comparison of hay yields, Iron, Brabham, Black Unknown, and Black have yielded the greatest quantity of hay per acre. On the sandy soils of this section, particularly those infested with wilt, the Brabham cowpea is excellent for both hay and seed. The Iron has been splendid for hay production, but low in seed yields. The Groit has been a good seed and hay producer. Early Bluff was used one year, but was entirely killed by wilt.

TABLE XI

COWPEA VARIETIES

EXPERIMENT STATION FARM, WEST RALEIGH, N. C.
1915, 1916, 1917 and 1918

For Seed				For Hay			
Variety	Per Cent Stand	Number of Days to Mature Seed	Yield of Seed Per Acre in Bushels	Variety	Per Cent Stand	Number of Days to Mature Hay	Yield of Hay Per Acre, Pounds
Groit	96	103	17.26	Wonderful	99	120	3767
Early Red	92	102	17.22	Monetta	99	92	3071
Whippoorwill	99	107	14.76	Black Unknown	98	92	2971
New Era	98	103	14.74	Groit	96	82	2948
Red Ripper	97	110	14.23	Whippoorwill	99	92	2822
Two-crop Clay	95	97	13.67	Iron	100	93	2717
Black Unknown	98	110	12.88	Black	97	90	2653
Black	97	107	12.87	Early Red	92	81	2633
Monetta	99	111	10.85	Brabham	99	99	2598
Taylor	83	110	10.62	Taylor	83	91	2527
Brabham	99	111	9.99	New Era	98	82	2299
Iron	100	111	8.31	Red Ripper	97	93	2152
Wonderful	99	140	4.35	Two-crop Clay	95	81	1941

TABLE XII

VARIETY COWPEAS

COASTAL PLAIN BRANCH STATION, ROCKY MOUNT, N. C.
1915, 1916, 1917 and 1918

FOR SEED				FOR HAY			
Variety	Per Cent Stand	Number of Days to Mature Seed	Yield of Seed Per Acre in Bushels	Variety	Per Cent Stand	Number of Days to Mature Hay	Yield of Hay Per Acre, Pounds
Groit	90	132	11.63	Iron	93	107	1891
Whippoorwill	85	132	10.96	Brabham	91	109	1851
Brabham	91	133	10.79	Black Unknown	97	109	1642
Early Red	95	132	10.42	Black	98	104	1641
Taylor	90	132	10.03	Groit	90	101	1608
Monetta	93	133	8.92	Monetta	93	104	1591
New Era	87	132	8.50	Taylor	90	102	1563
Black	98	132	8.34	Early Red	95	93	1524
Red Ripper	99	133	8.22	Red Ripper	99	104	1478
Iron	93	133	7.67	Whippoorwill	85	101	1370
Black Unknown	97	133	7.33	New Era	87	101	984
Two-crop Clay	96	130	4.45	Two-crop Clay	96	95	933

TRUCKING BRANCH STATION

The Trucking Branch Station lies in the Southeastern coastal Plain, near Willard, in Pender County. The soil type upon which this test was conducted is Portsmouth Sandy Loam.

Fourteen varieties of cowpeas have been grown here during the past three years to compare their yields of seed and hay. The average yields of these varieties are given in Table XIII. In the production of seed the varieties range from 8.33 bushels per acre from Groit, to none from Wonderful and Clay. Groit, Early Red, Two Crop Clay, and Whippoorwill have yielded the largest quantities of seed, and Wonderful, Brabham, Red Ripper, and Monetta have been best for hay in this section. For the production of seed and hay, Groit, Brabham and Monetta rank high.

SOYBEANS

FOR NORTH CAROLINA

Records show us that soybeans were used for human food in China, Japan and Manchuria at a very early date. They were introduced

FIG. 4. Virginia Soybeans, a good variety for hay.

into America in 1829, but received very little attention until the variety now known as the Mammoth Yellow was introduced about 1882. The introduction of this variety was followed by a decided increase in the production of the crop.

Prior to 1900, soybeans had not been grown very extensively in North Carolina. Since that date, their value and uses have become better known, and its production has steadily increased. At the present time it is quite an important crop, particularly in eastern North Carolina, ranking sixth in commercial importance among the crops of our State.

TABLE XIII

VARIETY COWPEAS

TRUCKING BRANCH STATION, WILLARD, N. C.
1915, 1916 and 1918

FOR SEED				FOR HAY			
Variety	Per Cent Stand	Number of Days to Mature Seed	Yield of Seed Per Acre in Bushels	Variety	Per Cent Stand	Number of Days to Mature Hay	Yield of Hay Per Acre, Pounds
Groit	98	104	8.33	Wonderful	88	111	3114
Early Red	99	104	7.93	Brabham	94	111	2836
Two-crop Clay	99	100	7.77	Red Ripper	88	89	2709
Whippoorwill	96	108	6.82	Monetta	98	89	2656
Black Unknown	94	110	6.78	Iron	97	89	2534
Taylor	89	108	5.91	Black Unknown	94	89	2414
Monetta	98	120	5.42	Whippoorwill	96	83	2246
Iron	97	120	5.06	Groit	98	83	2202
Brabham	94	120	4.86	Taylor	89	89	2008
Black	95	108	3.17	Clay	70	111	1862
New Era	78	104	2.95	Black	95	83	1691
Red Ripper	88	110	1.08	Two-Crop Clay	99	83	1556
Wonderful	88			Early Red	99	83	1256
Clay	70			New Era	78	83	938

Soybeans for Hay

The large yield of material together with the high food content makes the soybean one of the best hay crops for Southern conditions. When compared with alfalfa hay, soybean hay is its equal in every way, and is cheaper in price. A ton of soybean hay carries 22 pounds more protein, 86 pounds less of carbohydrates, and a little more than twice the amount of fats contained in alfalfa hay. Compared with other hays commonly fed in this State, it ranks very high, as is shown in Table XIV.

TABLE XIV

COMPARATIVE FEEDING VALUE OF HAYS

Hay	Water	Protein	Carbohydrates	Fats
Soybean	11.3	15.4	38.4	5.2
Cowpea	10.7	16.6	42.2	2.2
Alfalfa	8.4	14.3	42.7	2.2
Red Clover	15.3	12.3	31.1	3.3
Oats	15.0	9.3	39.0	2.3
Timothy	13.2	5.9	45.0	2.5
Johnson Grass	10.2	7.2	45.9	2.1
Corn Stover	40.5	3.8	31.5	1.1

(Representing pounds of food materials in one hundred pounds of hay.)

This table shows that soybean hay is surpassed, in protein, only by cowpea hay. In fact it is much richer than any of the other hays. Compared with oat and Timothy, two very popular hays, the soybean hay is decidedly superior, containing 6.1 per cent more protein, about the same amount of carbohydrates, and a little more than double the amount of fat in oat hay. When compared with Timothy, soybean hay contains nearly double the amount of protein, 6.4 per cent less carbohydrates, and more than double the amount of fats.

The yield of hay from soybeans, depends, to a large extent, upon local conditions, such as fertility of soil; preparation, cultivation, time of planting and the season. If the soil is fairly fertile and thoroughly prepared, with an average season soybeans should yield from 1 to 3 tons of hay per acre.

Because of its upright growth, the soybean is more easily harvested for hay than the cowpea. If planted thickly they can be cut easily with a mowing machine.

Soybean hay is not difficult to cure when handled properly. If hauled to the barn green, the hay is likely to mold, but if properly handled it cures bright and sweet, making an excellent hay. This may be done by cutting the beans after the dew is off, and allowing them to lie in the sun for a few hours until the leaves and stems have wilted. They are then raked in rolls and stacked on ventilated stacks in the field, or to the

side of the field, if the land is to be planted soon after the hay crop is taken off. After a few weeks in these stacks the hay will be properly cured. The hay may also be cured in small cocks in the field. When this method is used, the cocks should be turned every day or two until the hay is ready to haul to the barn. Hay cured in this way is always in danger of damage from rain. Soybean hay should never be cured on the ground as this causes a loss of leafy material.

Fig. 5. Ventilated Stacks for Curing Soybean or Cowpea Hay.

Soybeans for Seed

Unlike cowpeas, soybeans are grown extensively for seed production. Because of the high yields and the many uses for the seed and their products, the growing of soybeans for seed has become quite an important industry.

The yield of soybeans will depend, to a large extent, on local conditions. On the better soils of the Coastal Plain the yields have ranged between 20 and 40 bushels per acre, while 15 to 25 bushels is considered a good yield in the piedmont and mountain sections.

The method of harvesting soybeans depends, to a large extent, upon the amount grown. Small quantities may be pulled up by hand or cut with a reap hook and threshed out with a flail. One man should be able to thresh 5 to 6 bushels a day by this method when the plants are thoroughly dried. Where several acres are to be harvested, it will be necessary to use machinery of some kind. Several special harvesting machines are now on the market. Most of these machines thresh the beans in the field, leaving the stalks for pasturage and soil improvement. These harvesters gather from 60 to 75 per cent of the seed, the remainder being scattered on the ground or left on the stalks. The seed left,

however, are usually eaten by the hogs or cattle pastured after harvesting. In localities where oats are grown in rotation with soybeans, the reaper-and-binder is used for harvesting both and the threshing is done on a bean thresher or ordinary grain separator. If the beans are planted thick in the row, at the rate of 35 to 40 pounds, in three-foot rows, they may be cut with a mowing machine, placed in small cocks to dry and later stored or threshed with a grain separator or corn shredder. In using the grain separator, or shredder, care should be used to reduce the speed of the cylinders to one-half in order to avoid breaking the beans.

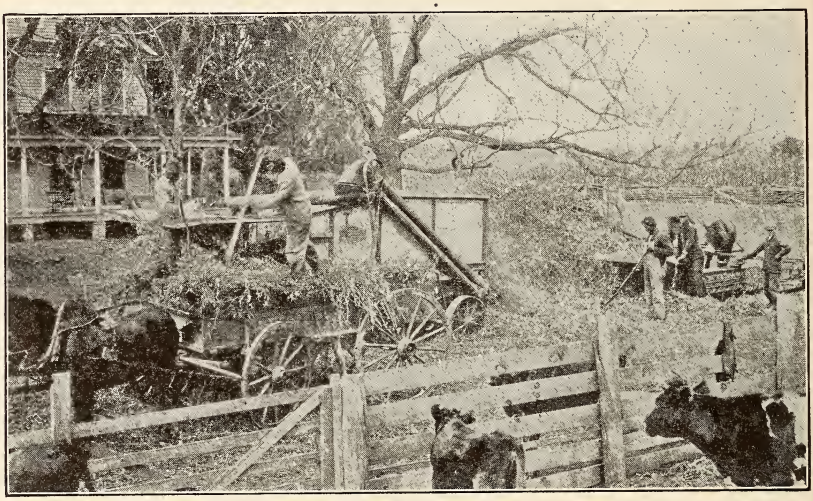

FIG. 6. The same machinery used in harvesting small grain may be used to advantage with soybeans.

Soybeans for Pasture

The soybean has no equal as a summer pasture crop for hogs. The large number of varieties, and their adaptability to all sections of our State, should make it one of our principal pasture crops. In the Coastal Plain section, the late varieties are already popular for this purpose. The later varieties should be used more generally, and the earlier varieties should be grown to extend the length of the pasturage season. In the piedmont and mountain sections, several early varieties are splendidly adapted for this purpose. Pasturage may be had from the first of August until January in most parts of the Coastal Plain and Piedmont sections by planting early, medium and late maturing varieties. For pasturage in the eastern part of the State, the Black Eyebrow, or Manchu, gives early pasturage, the Virginia or Haberlandt, medium, and Mammoth Yellow, late pasturage. The same varieties may be used in the piedmont and Mountain sections, except in sections where the seasons are short.

Soybeans for Soil Improvement

The soybean is not so well adapted to building up poor soils as the cowpea, but it is an excellent crop for maintaining the fertility of those soils which have already been built up by the use of velvet beans or cowpeas. It will not compete with weeds and grasses on poor land, without a great deal of care, and is not adapted to broadcast planting on such soils. When grown in rows and cultivated, the soybean will produce more seed and more organic material for turning under than the cowpea.

Fig. 7. The Haberlandt Soybean, a good variety for early hog pasture.

Methods of Culture

The culture for soybeans is about the same as for cowpeas, except the soybean requires a better seed bed. On poorly prepared seed beds, or when planted too deep, the soybean usually gives a poor stand. It seems to lack the power of pushing up through a crust, or through a deep layer of heavy wet soil. For this reason, the seed should not be planted more than 1 to 1½ inches deep. The seed bed should be thoroughly prepared so weeds will not get a start before the beans are large enough to cultivate.

When grown for seed, or alone for pasture, soybeans should be planted in rows two to three feet apart and cultivated. The soybean is not as well adapted to broadcast planting as the cowpea. In order to compare the yield of seed and hay from soybeans grown in rows and broadcasted, plantings were made in two-foot, forty inch, and broad-

casted plats at the Coastal Plain and Mountain Branch Stations. The results of these comparisons are given in Tables XV and XVI. In these studies, the Manchu bean, an early variety, and the Tokio, a mediumly late variety, were used. The broadcast plantings were seeded at the rate of 75 pounds to the acre, the two-foot rows at 45 pounds, and the forty inch rows at 30 pounds per acre. The results in each of the tables represent an average of three tests. Usually the row plantings have yielded from three to four times the amount of seed produced by the broadcast plantings and more hay. The hay from row plantings does not have the large percentage of objectionable weeds found in that from broadcast plantings.

Comparisons have also been made in which the plants were given different distances in the row. The plantings were made thick in forty-

FIG. 8. Soybeans grown in rows between corn for seed, pasture or soil improvement.

inch rows, and later thinned to three, six and twelve inches between plants in the row. The average yields of seed and hay during the three years of this test are included in Table XVII. Three varieties, Haberlandt, Virginia, and Mammoth Yellow, were used in these studies. The Haberlandt bean is mediumly early, short and branchy; the Virginia, mediumly early, slender and tall, and the Mammoth Yellow is late, and tall, with heavy branches. In this work, the plants left thickest in the row produced the largest quantity of seed and hay.

Rate of Seeding Soybeans

Soybeans planted in rows should be seeded thicker than cowpeas. Being an upright plant, it requires less room between rows, or in the row, than the cowpea. In two-foot rows they should be seeded at the rate of 45 to 50 pounds per acre, and in three-foot rows they should be seeded at the rate of 30 to 35 pounds per acre. In order to determine the best rates

for broadcasting, three years tests have been made at the Coastal Plain and Mountain Branch Stations. In these tests, rates of 30, 60, 90, and 120 pounds per acre were compared. The Virginia soybean, a very good hay variety, was used in planting these tests. Tables XVIII and XIX contain the average yields for the different rates tested during three years. According to these results, the seedings of 90 and 120 pounds per acre have given the largest yield of actual soybean hay. From plots on which the lighter seedings were made the hay contained a large percentage of objectionable weeds and grass.

TIME OF PLANTING SOYBEANS

The best time for planting the soybean will vary with the climatic conditions of the different parts of the State and will depend, to some extent, upon the crop grown in rotation or along with it. In order to secure data on the time of planting tests were conducted on the Mountain Branch Station and the Coastal Plain Branch Station, in which plantings were made every 15 days, beginning May 1, and extending through July 15. The results of these tests are given in Tables XX and XXI. In the eastern part of the State the soybean may be planted as early as corn; though the best results have been secured from plantings made between May 1 and June 1. Plantings made as late as July 1 will mature, though the yield will not be so good as those made between May 1 and June 1. For the upper piedmont and mountain sections plantings made between May 15 and June 15 have given the best yields.

FERTILIZER FOR SOYBEANS

The fact that cowpeas and soybeans are able to take a part of their food from the air, is no reason why they should not receive additional plant food in the form of commercial fertilizers. For the sandy soils of the eastern part of the State, an application of 150 to 200 pounds of fertilizer containing 8 per cent phosphoric acid, 2 per cent nitrogen and 2 per cent potash will give good results. The nitrogen may be left out when the fertilizer is to be used on soils already rich in nitrogen, and the potash may be left out of mixtures used on most piedmont and mountain soils.

TABLE XV

Soybean Culture Experiments

MOUNTAIN BRANCH STATION, SWANNANOA, N. C.

Variety.	Method of Seeding.	Yield Seed Bu. per A.	Yield hay lbs. per A.	Per cent of hay weeds.
Tokio	Broadcast	.0	3254	62.50
Tokio	24 in. row	3.60	7385	0
Tokio	40 in. row	3.60	5700	0
Manchu	Broadcast	1.88	4245	50.00
Manchu	24 in. row	8.50	1780	0
Manchu	40 in. row	9.25	2550	0

TABLE XVI

SOYBEAN CULTURE EXPERIMENTS

COASTAL PLAIN BRANCH STATION, ROCKY MOUNT, N. C.

Variety	Method of Seeding.	Yield seed Bu. per A.	Yield hay lbs. per A.	Per cent. of hay weeds.
Tokio	Broadcast	3.28	1183	61.25
Tokio	24 in. row	10.87	1253	0
Tokio	40 in. row	10.11	1180	0
Manchu	Broadcast	1.92	1463	76.25
Manchu	24 in. row	6.83	1003	0
Manchu	40 in. row	8.83	940	0

TABLE XVII

SOYBEAN CULTURE EXPERIMENT

EXPERIMENT STATION FARM, WEST RALEIGH, N. C.
1915, 1916 and 1917

Variety	Distance Between Plants in Inches	Distance Between Rows in Inches	Yield of Seed Per Acre in Bushels	Yield of Hay Per Acre in Pounds
Haberlandt	3	40	14.42	2781
Haberlandt	6	40	12.83	2635
Haberlandt	12	40	10.64	2037
Virginia	3	40	13.64	2465
Virginia	6	40	13.07	2371
Virginia	12	40	10.77	1707
Mammoth	3	40	22.07	3370
Mammoth	6	40	20.94	3276
Mammoth	12	40	20.54	3161

SOYBEAN VARIETIES

Most farm crops that have been cultivated for several centuries have developed a large number of varieties. This is particularly true of the soybean. Since these varieties differ in their habit of growth and in the length of the season required for maturity, they will also differ in their adaptability to different sections of the State. Several varieties have been compared on six of the branch station farms of the State for the purpose of securing this information. The farms are so located as to represent the different climatic conditions and principal soil types of the State. All of the comparisons for hay and seed were made in three foot rows.

MOUNTAIN BRANCH STATION, SWANNANOA, N. C.

During the past four years, ten of the most promising varieties of soybeans have been compared at this farm. The average results of the four years tests are included in Table XXII. These varieties range in yield between 19.38 bushels and 6.38 bushels per acre, the highest yielding variety producing nearly three times the amount of seed yielded by the lowest. Medium Yellow, Haberlandt, Austin and Virginia led in yield of seed. On account of the short season here, the mediumly early varieties have yielded better than the late varieties like Mammoth Yellow and Tokio.

The table also contains the yields for hay during the same period. The best hay yields were secured from Chiquita, Virginia, Wilson, and Medium Yellow. Because of its habit of growth and quality of hay, the Virginia bean is the best hay bean for this section. The Medium Yellow is not desirable for hay on account of the fact that it sheds its leaves early, and its seed shatter badly at maturity. The Virginia bean for hay and the Haberlandt for seed and hog pasture are the best varieties for this section.

PIEDMONT BRANCH STATION, STATESVILLE, N. C.

Eight of the best soybean varieties have been included in the tests on this farm during the past five years. The average results for seed

TABLE XVIII

RATE OF SEEDING SOYBEANS

COASTAL PLAIN BRANCH STATION, ROCKY MOUNT, N. C.

Variety	Rate Seeding lbs. per A.	Yield Seed per A. in bu.	Yield hay per A. lbs.	Per cent hay weeds
Virginia	30	10.39	2580	32.20
Virginia	60	10.83	2287	30.67
Virginia	90	13.61	2950	9.50
Virginia	120	13.40	2837	3.33

TABLE XIX

RATE OF SEEDING SOYBEANS

MOUNTAIN BRANCH STATION, SWANNANOA, N. C.

Variety.	Rate seeding lbs. per A.	Yield seed bu. per A.	Yield hay lbs. per A.	Per cent of hay weeds
Virginia	30	1.5	5506	75.00
Virginia	60	.71	7076	67.50
Virginia	90	1.75	6886	50.00
Virginia	120	.68	4880	20.00

TABLE XX

DATE OF SEEDING SOYBEANS

MOUNTAIN BRANCH STATION, SWANNANOA, N. C.

Variety.	Date of Seedng.	Bu. Seed per A.	Lbs. hay per A.
Haberlandt	May 1	12.09	5070
Haberlandt	May 15	12.46	5040
Haberlandt	June 1	10.58	4515
Haberlandt	June 15	10.13	4470

TABLE XXI

DATE OF SEEDING SOYBEANS

COASTAL PLAIN BRANCH STATION, KINGSBORO, N. C.

Variety.	Date of Seedng.	Bu. seed per A.	Lbs. hay per A.
Haberlandt	May 1	13.58	1900
Haberlandt	May 15	13.75	1690
Haberlandt	June 1	13.00	1820
Haberlandt	June 15	13.50	1700
Haberlandt	July 1	13.00	1310
Haberlandt	July 15	17.08	910

FIG. 9. Soybean varieties, Experiment Station Farm.

and hay yields are given in Table XXIII. Mammoth Yellow ranks first in yield of seed per acre, and Tar-Heel Black yielded the largest quantity of hay. Mammoth Yellow, Haberlandt, and Virginia are best varieties for this section. Tar-Heel Black yields a large quantity of fair hay, but has not been so good for seed production as Mammoth Yellow.

Variety Test at Experiment Station Farm, West Raleigh, N. C.

At this station more than 100 varieties of soybeans have been grown for comparison. Only a few of these showed sufficient merit to be retained in the test more than two years. Most of the seeds of these varieties have been furnished by the Office of Forage Crop Investigations of the Bureau of Plant Industry. Varieties that showed some promise here were later distributed to the other farms, and the best of these were placed with growers who were prepared to grow them for seed. During the past four years, 13 varieties have been compared for yields of seed and hay. The average results of these tests are contained in Table XXIV. Mammoth Yellow has been the best for seed production, but has been closely followed by Tar-Heel Black, Mammoth Brown, Chiquita and Tokio. Tar-Heel Black, Chiquita, and Mammoth Yellow have yielded the largest quantity of hay. Of these varieties, the Chiquita produces the best quality of hay on account of its finer stems.

Variety Tests at Coastal Plain Branch Station, Rocky Mount, N. C.

The soybean is grown more generally throughout the Coastal Plain than any other sections of the State. Here it has been grown for seed production for several years, but recently has become very popular as a pasture crop for hogs. The Mammoth Yellow is one of the oldest and most generally grown varieties in this section, though Tar-Heel Black and Mammoth Brown have been grown to some extent.

At this Branch Station, twelve varieties have been compared during the past four years. Their average yield of seed and hay are given in Table XXV. According to these results, Mammoth Yellow, Virginia and Tar-Heel Black are the best varieties for this section. Mammoth Yellow has been, without doubt, the best seed producer. Tar-Heel Black has produced the largest quantity of hay, but its quality has not been so good as that of the Virginia.

Variety Tests at Trucking Branch Station, Willard, N. C.

The Trucking Branch Station represents the southeastern portion of the Coastal Plain Section, which is particularly well adapted to soybeans. In this section, the soybean fits in well at a catch crop after early vegetables, and helps to retain the fertility so necessary for the successful production of truck crops.

Eight varieties were included in the tests here during two years. The average yields of seed and hay, and the number of days required to mature the different varieties, are given in Table XXVI. According to these results, Mammoth Yellow and Virginia are the best varieties for this section. The Virginia bean is a splendid hay variety, on account of its small leafy stems and the fact that it holds its leaves well.

TABLE XXII

SOYBEAN VARIETIES

MOUNTAIN BRANCH STATION, SWANNANOA, N. C.
1915, 1917 and 1918

For Seed				For Hay			
Variety	Per Cent Stand	Number of Days to Mature Seed	Yield of Seed Per Acre in Bushels	Variety	Per Cent Stand	Number of Days to Mature Hay	Yield of Hay Per Acre, Pounds
Medium Yellow	99	146	19.38	Chiquita	99	128	5340
Haberlandt	97	147	18.20	Virginia	99	124	5224
Austin	99	147	16.77	Wilson	99	124	5180
Virginia	99	147	15.25	Medium Yellow	99	119	4560
Wilson	99	146	14.48	Austin	99	126	4133
Manchu	97	134	14.21	Haberlandt	97	123	3920
Black Eyebrow	99	134	13.16	Tokio	99	133	3890
Tokio	99	162	11.34	Mammoth	98	133	3000
Chiquita	99	148	11.12	Manchu	97	118	2810
Mammoth Yellow	98	161	6.38	Black Eyebrow	99	118	2457

TABLE XXIII

PIEDMONT BRANCH STATION, STATESVILLE, N. C.
1915, 1916, 1917 and 1918

For Seed				For Hay			
Variety	Per Cent Stand	Number of Days to Mature Seed	Yield of Seed Per Acre in Bushels	Variety	Per Cent Stand	Number of Days to Mature Hay	Yield of Hay Per Acre, Pounds
Mammoth Yellow	93	138	16.62	Tar Heel Black	84	112	3441
Haberlandt	84	119	13.96	Mammoth Yellow	93	115	3066
Tar Heel Black	84	137	13.33	Haberlandt	84	94	2749
Virginia	94	119	12.87	Chiquita	83	104	2674
Wilson	97	119	9.97	Virginia	94	94	2330
Chiquita	83	130	7.44	Arlington	98	95	2250
Arlington	98	119	7.05	Wilson	97	94	1967
Black Eyebrow	77	116	6.82	Black Eyebrow	77	90	1110

TABLE XXIV

SOYBEAN VARIETIES

EXPERIMENT STATION FARM, WEST RALEIGH, N. C.
1915, 1916, 1917 and 1918

FOR SEED				FOR HAY			
Variety	Per Cent Stand	Number of Days to Mature Seed	Yield of Seed Per Acre in Bushels	Variety	Per Cent Stand	Number of Days to Mature Hay	Yield of Hay Per Acre, Pounds
Mammoth Yellow	97	148	22.49	Tar Heel Black	99	110	4072
Tar Heel Black	99	145	20.48	Chiquita	97	106	3292
Mammoth Brown	96	144	19.44	Mammoth Yellow	97	113	3249
Chiquita	97	131	18.46	Mammoth Brown	96	108	3122
Tokio	99	148	18.43	Tokio	95	113	2426
Virginia	95	117	13.45	Virginia	96	85	2392
Arlington	96	118	13.77	Arlington	96	90	2279
Wilson Black	93	114	13.46	Haberlandt	84	85	2214
Haberlandt	84	112	13.43	Medium Yellow	98	88	2159
Medium Yellow	98	118	12.99	Wilson Black	93	85	2080
Austin	92	112	12.03	Austin	92	86	1933
Black Eyebrow	88	102	11.37	Manchu	92	77	1404
Manchu	92	102	11.27	Black Eyebrow	88	77	1283

TABLE XXV

SOYBEAN VARIETIES

COASTAL PLAIN BRANCH STATION, ROCKY MOUNT, N. C.
1915, 1916, 1917 and 1918

FOR SEED				FOR HAY			
Variety	Per Cent Stand	Number of Days to Mature Seed	Yield of Seed Per Acre in Bushels	Variety	Per Cent Stand	Number of Days to Mature Hay	Yield of Hay Per Acre, Pounds
Mammoth Yellow	87	150	23.92	Tar Heel Black	86	116	3214
Virginia	97	128	19.63	Mammoth Yellow	87	121	3028
Wilson Black	97	128	17.39	Virginia	97	102	2470
Tar Heel Black	86	145	17.33	Chiquita	98	110	2470
Medium Yellow	96	125	12.21	Wilson	97	100	2466
Haberlandt	92	125	12.04	Arlington	97	107	1975
Arlington	97	136	11.63	Medium Yellow	96	102	1963
Chiquita	98	143	10.42	Haberlandt	92	100	1623
Austin	94	129	10.04	Austin	94	104	1620
Tokio	84	150	8.88	Tokio	84	124	1614
Black Eyebrow	94	113	8.33	Black Eyebrow	94	82	1291
Manchu	95	113	4.42	Manchu	95	82	642

TABLE XXVI

SOYBEAN VARIETIES

TRUCKING BRANCH STATION, WILLARD, N. C.
1915 and 1916

For Seed				For Hay			
Variety	Per Cent Stand	Number of Days to Mature Seed	Yield of Seed Per Acre in Bushels	Variety	Per Cent Stand	Number of Days to Mature Hay	Yield of Hay Per Acre, Pounds
Mammoth Yellow	98	140	25.57	Mammoth Yellow	98	120	6977
Virginia	94	112	18.12	Tar Heel Black	98	115	5473
Wilson Black	98	112	13.85	Virginia	94	95	4177
Black Eyebrow	93	106	11.26	Wilson Black	98	95	3323
Tar Heel Black	98	135	10.40	Peking	94	95	2479
Haberlandt	94	112	9.59	Black Eyebrow	93	71	1883
Peking	94	112	6.21	Haberlandt	94	85	1483
Early Dwarf Green	89	110	4.03	Early Dwarf Green	89	85	1230

COWPEAS AND SOYBEANS COMPARED

In comparing the cowpea and soybean, it is not so much a matter of determining which is the best crop, but which is adapted to special uses on the farm. As a matter of fact, both of these crops could be grown with profit on most farms of the State.

At the time of planting, soybeans require a better seed bed, and usually give a poor stand if planted deeper than one and a half inches. The soybean will stand a considerable amount of frost in the spring or fall, while the cowpea is very sensitive to cold. With the exception of a few varieties, the soybeans are upright in growth, being easy to harvest for hay or seed. Cowpeas on the other hand, are viney plants and therefore more difficult to harvest. Soybeans mature at one time, while the cowpeas usually continue to grow and produce until frost. The soybean produces more seed and hay when planted in rows, though it is not adapted to broadcast planting, especially on poor land. The cowpea is best for building up poor soils.

In order to compare the yields of seed and hay from the best varieties of soybeans and cowpeas, the following tables have been prepared from the results at the different branch stations. In each case the soybeans and cowpeas were grown under the same conditions in three-foot rows.

COWPEAS AND SOYBEANS COMPARED

MOUNTAIN BRANCH STATION, SWANNANOA, N. C.

Variety.	Yield seed per A. in bu.	Yield hay per A. in lbs.	
Virginia	15.25	5225	Soybean
Groit	5.06	4010	Cowpea
Haberlandt	18.20	3920	Soybean
Early Red	6.87	2080	Cowpea
Manchu	14.21	2810	Soybean
Taylor	5.89	2700	Cowpea

COWPEA AND SOYBEAN COMPARISON

PIEDMONT BRANCH STATION, STATESVILLE, N. C.

Variety.	Yield seed bu. per A.	Lbs. hay per A.	
Mammoth Yellow	16.62	3066	Soybean
Groit	12.50	2482	Cowpea
Haberlandt	13.96	2749	Soybean
Monetta	5.59	3059	Cowpea
Virginia	12.87	2330	Soybean
Early Red	12.38	2192	Cowpea

JULY, 1918 TECHNICAL BULLETIN 15

A MONOGRAPH ON TREMBLES OR MILKSICKNESS AND WHITE SNAKEROOT

F. A. WOLF R. S. CURTIS
AND B. F. KAUPP

NORTH CAROLINA
AGRICULTURAL EXPERIMENT STATION
CONDUCTED JOINTLY BY THE
STATE DEPARTMENT OF AGRICULTURE
AND THE
NORTH CAROLINA STATE COLLEGE OF
AGRICULTURE AND ENGINEERING

RALEIGH AND WEST RALEIGH

THE NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION

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CONTENTS

A MONOGRAPH ON TREMBLES, OR MILKSICKNESS, AND WHITE SNAKEROOT.*

By

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Introduction

For a number of years, complaints have come to this Station through letters from farmers, county agents, and extension workers, of the occurrence within the mountainous sections of North Carolina of a peculiar malady known as Trembles. This disease annually causes very considerable losses of horses, cattle, sheep, and hogs. Furthermore, in sections where this disorder is present, the belief is unanimously and firmly held that man may contract the disease by the ingestion of milk, hence the name "milksickness" which physicians employ, of certain milk products and of flesh of animals affected with trembles.

A questionnaire was therefore sent out to learn, among other things, something of the distribution of trembles, the seasonal incidence of the disease, the kinds of animals affected, preventive and curative measures employed, losses, and opinions as to the cause. It was found from these reports that the disease very probably occurs in the mountainous portions of all the counties in western North Carolina and in the immediately adjacent sections of States having similar conditions. The losses, furthermore, to the live-stock interests are so grave, since the danger of an outbreak is ever present and since so few affected animals recover, except when cases are discovered and treated in the incipient stages, that the farmer is reluctant to make any considerable investment in stock in sections where the malady is likely to occur.

Not only is an additional risk placed upon live-stock production by the presence of this disease, but it also discourages certain industries such as creameries and cheese factories whose success depends upon a lively interest in the growing of domestic animals. The popular attitude toward the disease is typified by the report of one county agent, who asserts that in his section trembles is the limiting factor in the establishment of cheese factories.

*The authors hereby gratefully acknowledge the hearty cooperation of Director B. W. Kilgore and Mr. Dan T. Gray in providing ways and means for conducting this investigation. Furthermore, appreciation is, by this means, expressed for the several services rendered by our colleagues Mr. Earl Hostetler, Mr. George Evans, Mr. L. I. Case, Mr. A. L. Jerdan, Mr. F. T. Peden, Mr. W. R. Radford, Dr. J. I. Handley, Dr. L. F. Koonce, and Mr. A. C. Foster. Thanks are also due Mr. E. D. Bowditch, formerly Demonstration Agent of Clay County, from whom the white snakeroot was procured, Mr. M. R. Penland, for daily shipments of the weed, and Mr. E. McPhaul for much of the labor in connection with feeding experiments and the keeping of records.

Numerous beliefs, too, many of which are shrouded in mystery, were found to be entertained in regard to the causation of the disease. An examination of the voluminous literature on trembles and milksickness revealed the fact that many of these beliefs had been expressed in print, and that even critical investigations dealing with the etiology of the malady contained diverse conclusions. The one apparently most widely accepted by investigators, however, is that the disease is of bacterial origin. This opinion is contained in a recent bacteriological text-book* which states that the disease "is caused by the growth of and consequent absorption of toxic principles from the infective agent (*Bacillus lactimorbi*) lodged primarily in the small intestine and, secondarily, in the liver and other organs of the body."

In view, therefore, of the immense economic importance of trembles and milksickness and of the conflicting statements in regard to its etiology, a study of the disease was begun in the summer of 1916. This work was continued throughout the succeeding year and a considerable body of data has been secured bearing on the cause, transmission, symptoms, and pathological anatomy of the disease. A preliminary report on the cause of trembles has been published,† but since the subject-matter of this report is included in the present paper, further mention of it is deferred at this place. It is deemed advisable, furthermore, since the readers of this bulletin may not have ready access to published accounts of milksickness, and consequently may not be familiar with the literature bearing on the disease, to include a considerable body of historical information.

HISTORICAL ACCOUNT OF THE OCCURRENCE OF TREMBLES AND MILKSICKNESS

This disease has for a long time been known to occur within the United States. Attention was first directed to its presence by a physician, Dr. Daniel Drake, who published, in 1810, a brief account of it under the title "New Disease" in his Notices Concerning Cincinnati. This account, which was communicated to Dr. Drake, was based upon observations made in Madriver County, Ohio, by Dr. Barbee. Drake's account consisted of a concise statement of the symptoms, kinds of animals affected, conditions favoring its prevalence, and remedial and palliative measures. This account was later reprinted by Drake as an editorial addition to an article by McCall (1830). While this note in 1810 is the first published account, the disease is known with cer-

Vide, Marshall, Charles E., edit. *Microbiology*, a text-book of micro-organisms, general and applied. 2d edition, p. 785, 1917.

†Journal of Agricultural Research. June, 1917.

tainty to have existed prior to that time. Drake (1836) makes the statement "that this malady has been observed in some parts of North Carolina more than sixty years ago (*i. e.,* prior to 1776) and that it had been an endemic in certain localities of Tennessee, Kentucky, and Ohio from their first settlement." Coleman (1822) states that "sick stomach has been prevalent in some of the western counties of the State of Ohio since their first settlement." McCall (1823) makes specific mention of several cases which occurred in North Carolina between 1779 and 1800.

Rawlings (1874) also makes reference to "its first avowed recognition in the State of North Carolina—now over ninety-six years ago" (*i. e.,* prior to 1778). It is further stated in this account that "the disease followed emigration in its westward march from North Carolina to Tennessee and Kentucky, and prevailed in various parts of Ohio, Indiana, and Illinois. The report of Carney (1847) mentions the occurrence of the disease, "I think sixty or seventy years ago (1777 or 1787) in the Carolinas" and "upwards of fifty years since, it prevailed in Kentucky." In speaking of the disease in Tennessee, Lea (1821) asserts that "as soon as settlements commenced in the county of Franklin, about 12 or 15 years since, near the mountain, many cattle were lost from some unknown poison, the nature of which is still a mystery among the inhabitants. Occasionally whole herds have been found dead in some sequestered cove of the mountains." There are also early records of the disease in Indiana made by Faux (1823) and in northwestern Missouri by Long (1823).

An interesting historical account comes from the pen of Flagg (1836) from observations made while he was in Monroe County, Illinois. This states that "a mysterious disease called the *milk sickness*—because it was supposed to be communicated by that liquid—was once alarmingly prevalent in certain isolated districts of Illinois. Whole villages were depopulated; and though the mystery was often and thoroughly investigated, the cause of the disease was never discovered. By some it was ascribed to the milk or to the flesh of cows feeding upon a certain unknown poisonous plant found only in certain districts, by others to certain springs of water, or to the exhalations of certain marshes. The mystery attending its operations and its terrible fatality at one period created a panic in the settlers; nor was this at all wonderful. The disease appears now to be vanishing."

Other writers share this idea that the malady is disappearing since Winans (1840) states that "I had three to five hundred patients during the whole time the disease prevailed. It has now nearly or quite vanished away." Beach (1883) in speaking of the disease in Madison

County, Ohio, "presumes nearly one-fourth of the pioneers and early settlers died of this disease." Compton (1881) in discussing conditions in Dubois County, Indiana, in 1815, says that "more than half the deaths that occurred in that section were from milksickness. It was also very fatal among stock."

While these opinions represent the belief of a considerable number who have known this disease, it is by no means universally shared. Among those who have expressed themselves differently may be cited Smith (1874) of Kenton, Ohio, who states in a letter to a medical journal, "We are having, this fall, a regular epidemic of what is generally called milksickness or trembles. I have treated upwards of thirty cases." In an article by Gray (1881) twelve cases of so-called gastritis developed among the consumers of butter from a certain farm. Three of these came under his observation and were apparently genuine cases of milksickness. Shapard (1892), of Winchester, Tenn., believed that the disease was as prevalent as at any time within the past fifty years. As recently as 1907, McCoy (1907) investigated an epidemic which resulted in six deaths in Macon County, Tenn. A recent report by Selby (1917) from the Ohio Station records the death from trembles of a cow at Sharpsburg, Ohio, in 1912, and of two at Johnstown, Ohio, in 1915. A communication was furthermore received at the Ohio Station in 1916 concerning the death of a young woman near Cygnet, Ohio, from milksickness.

Examinations of records of this disease in the various medical journals indicate that milksickness was more prevalent during the first half of the nineteenth century than during the latter half. This is to be expected since the lands in which white snakeroot (Eupatorium urticaefolium) grows have gradually been cleared and brought under cultivation. Even those who did not recognize this weed as the etiological factor in the production of this malady unanimously agree in the observation that thorough clearing and cultivation of the land will transform a dangerous area into a safe one (Drake, 1849; Crook, 1897; Pickard, 1857; Way, 1893).

Several reasons may be brought forward to show that the relative prevalence of this disease in times past cannot now be determined with any degree of exactness. In the first place, the International Classification of Diseases and Causes of Death does not recognize the existence of milksickness. This is not surprising, when attention is directed to the fact that at the time when the disease was most prevalent some writers, who expressed themselves voluminously on milk sickness, were very skeptical as to the existence of any such disease. Among these are Yandell (1852), who in criticising the various publications dealing

with the cause of the disease, gives it as his opinion that "the various accounts of this disorder nullify each other; and the mind is left in extreme doubt whether there is anything specific in milksickness." In discussing the existence of milksickness, Anderson (1867) has asserted that it is "a mere matter of credulous fancy." Other writers, as Chapman (McCall, 1823), Thompson (1854), and Bowen (Bailey, 1888) only go so far as to declare their disbelief in its existence.

A second reason for failure to determine the relative prevalence of this disease formerly is that health authorities have refused to record deaths reported under the name of milksickness. Again, genuine cases of milksickness have no doubt been diagnosed as gastritis, typhoid fever, ptomain poisoning, etc. This is to be expected since physicians have not had occasion to observe the malady while receiving their medical training, and so do not always identify it in practice.

The Cause of Trembles and Milksickness.

The etiology of this disorder has been the subject of considerable speculation and investigation, but no one appears to have presented any convincing body of data in support of his conclusions. The solution of this question was regarded as of so much importance in the early part of the past century that rewards were offered by several State legislatures for the discovery of the cause. Even as late as 1904, Osler (1904) in addressing medical officers of the United States Army calls attention to this as one of the intricate unsolved problems.

Numerous articles have been written on the causation of this disease. In a general way, these can be classified as supporting one of the three following theories: (a) mineral poison theory, (b) germ theory, and (c) poisonous plant theory. One finds advocates also of other more or less plausible hypotheses some of which are mentioned later in this report. It is believed that the writers' evidence can best be presented after brief consideration has been given to some of the more important published accounts on this phase of the problem.

a. Mineral Poison Theory.

A number of observers, among whom are Shelton (1836) in Alabama, White (1836) in Indiana, and McAnelly (1836) in Kentucky, held that animals while grazing obtained some poisonous mineral which was present in the soil in affected regions. The last of these men believed also that this poison was present in well water and accounted for the occurrence of the disease in autumn by the lowering of the water table resulting in the poison becoming "more concentrated."

Among the minerals held to be the cause of milksickness are arsenic, copper, mercury, cobalt, lead, and aluminium. Seaton (1842) was a very vigorous supporter of the view that arsenic was the cause of the disease. His arguments were as vigorously opposed by Drake (1842) and by Yandell (1852).

McCoy (1907) failed to produce in guinea pigs any condition remotely resembling trembles in feeding experiments in which cobalt, lead, and arsenic were employed.

Moseley (1909) from feeding experiments with rabbits came to the conclusion that trembles was due to aluminium phosphate and that animals get this substance by eating white snakeroot. Proof of this claim consisted in feeding aluminium, which was present in the ash of white snakeroot and in the milk and butter of affected cows, and in developing trembles by the feeding of aluminium phosphate. He found this substance also in the ash of Bigelovia (rayless goldenrod) sent from New Mexico, where ranchmen claimed that it caused trembles among their cattle. In his experiments similar effects followed the feeding of rayless goldenrod, white snakeroot, and aluminium phosphate. Another paper published by Moseley (1910) about a year later affirms that soda exerts an antidotal effect upon aluminium phosphate.

One of the most potent reasons urged that the disease is associated with the soil itself, is a fact quite universally agreed upon by all observers. Cattle pastured upon particular tracts of land acquire milksickness, whereas others on adjoining pastures never show any sign of the disease. These milksick areas are believed to be so sharply delimited that farmers have fenced off areas to prevent the access of stock. In some places the changing of the fence so as to include even a few yards of uncleared land is held to be responsible for an outbreak of trembles. In White County, Tenn., McCoy (1907) states that the disease has been very rare in the locality of Milksick Mountain since it was fenced about sixty years ago. These enclosed areas sometimes occupy only a few square rods. Shelton (1836) records the fact that "in Blount County, Tenn., there is a locality embracing not more than ten or fifteen acres on which the disease has been known to originate for nearly, perhaps quite, forty years."

Wooded land has been held by a considerable number of observers to be essential for the existence of the disease. Drake (1841) from observations made in Ohio says "trembles in cattle, horses, sheep, and hogs are produced by their frequenting the densely timbered table land which from its flatness abounds in wet places and ponds, indicated by the presence of lofty white elms, black walnuts, maples, burr oaks, and other trees which delight in a rich moist soil." It is furthermore claimed

by Lea (1821) and Beach (1884) that cattle may contract trembles if left overnight in such areas, but if they are removed before dark the disease can be avoided. When such wooded land has been cleared, it is rendered harmless. Crook (1857) claims that "in no instance has it ever been known in this county (Spencer County, Ind.) during any other than the grazing season, and then *only* upon lands that had never been in cultivation." This is in agreement with the claims made by Bennett (1822), Pickard (1857), and Simon (1888).

Attempts have been made, also, to associate the disease with certain soil types. Seaton (1841) claimed that it occurred only where sandstone entered largely into the composition of the soil. Those who did not agree with this view based their opinion upon the wide geographical distribution of milksickness with the consequent wide variety of geological peculiarities.

Another observer, Allen (1878), who believed that the disease is closely associated with the soil, records the peculiar instance that in certain localities in Effingham County, Ill., cattle lick large holes in the earth, after which many of them die.

In a considerable number of instances, water from infected areas has been held to be responsible for the disease. White, as early as 1836, mentions instances of outbreaks among cattle and sheep attributed to water. Beach (1883) gives an account of trembles in cattle contracted after having eaten hay from a meadow which had been flooded by surface drainage from a tract of land notorious for producing the disease. More recently Lyday (1896) maintains that in North Carolina the drinking of water from streams that flow from milksick coves is responsible for the disease. Fulton (1884) cites an instance in Logan County, Ohio, where cattle had taken the disease until a certain spring was fenced off, whereupon there was no more trouble. Credible informants told him of the disease in cattle accustomed to be watered at a certain well in Clark County, Ohio. When the well was closed, the disorder disappeared. He also recounts an instance of "a farm in Hardin County on which members of every family that has ever lived there have had the disease. On that farm I have attended patients who said they had not used meat, milk, butter, or cheese for weeks, guarding against the disease. The presumption, therefore, was that they and also those of previous families that had lived there had obtained it directly from the water."

Others have considered water responsible for the transmission, and thus indirectly allign themselves with the germ theory to be next discussed. McAnelly (1836) states in support of water as the agency of transmission, that "the disease sometimes prevails in the human spe-

cies in districts where the inferior animals are comparatively exempt and frequently where none of them are known to be affected at that time." The following singular statements by Brewington (1876) express belief in the same idea: "I do not believe that in this vicinity there is one in fifty persons that take the disease who gets it by using milk or butter from diseased animals. In many places where the disease used to be most prevalent, the people used water from wells for cooking and drinking, but since they built cisterns and use water from them exclusively, they are entirely exempt from the disease."

b. Microbic Theory

Several early students of milksickness doubted the validity of the mineral poison theory as an explanation of the causation of the disease and manifested a belief in the microbe theory. They did not have the advantages, however, of modern bacteriological technic and, basing their judgment largely on the transmissibility of the disease, concluded that it must be caused by some microscopic organism. Both Wright (1827) and Reed (1856) felt that the failure of chemical studies to show the presence of a mineral poison and of botanical studies to inculpate any poisonous plant indicated that the cause must be sought among cryptogamic parasites.

Because of the transmission of the disease through meat and milk, Burger (1825) compared milksickness with anthrax. Heeringen in 1843, twelve years before the discovery of the anthrax bacillus, and Heusinger in 1853 also pointed out certain points of similarity between milksickness and anthrax. Wood (1858) on purely *a priori* grounds argued causation by a germ. The passage of the disease from one body to another and "its multiplication in the system" inclined Byford (1855) and DeBruler (1858) to the germ theory. Philips (1877) found "a great number of living, moving, spiral bacteria" in the freshly drawn blood and in the urine of a typical case. Woodfin (1878), too, believed that milksickness is a specific infection. Gardner (1880) reported finding "countless multitudes of actively moving, writhing, twisting bacteria" in the blood of a heifer suffering from trembles and in dogs affected by eating the flesh of this heifer. He furthermore found the same organism in the blood of two human patients, in the water of a spring which supplied this stricken family, and in milk. Microscopic examinations of blood by Schmidt (1877) failed to reveal the presence of bacteria.

Logan (1881) committed himself to the statement that the disease must be due to a "contagium vivum."

It is a common belief in some sections of the State that cattle exposed at night in "milksick areas" contract the disease. This has suggested conveyance of the infection through the bites of arthropods or certain insects.

A considerable number of writers who have studied the disease more recently than the ones just reported accept the theory of a parasitic origin of the disease. Among them are Maurel (1884), Boggs (1907), McCoy (1907), Crawford (1908), Jordan and Harris (1908, 1909), and Luckhardt (1909). The three last named authors alone have reported studies upon a definite microscopic organism. Jordan and Harris (1908, 1909), in their two extensive accounts, record the finding of an undescribed spore-forming bacterium, which they designate as Bacillus lactimorbi, in the liver, bile, and spleen of a heifer, in the liver of her fetal calf, in the pericardial fluid and gut nodule of a horse, in the brain, heart blood, and liver of lambs, in the feces of nonfatal cases in man, in the milk of cows, in the soil of milksick regions and in regions where milksickness has never been known, in normal cow dung, and on various grain and forage plants. They succeeded in several instances in isolating B. lactimorbi in pure culture from the heart blood and from certain internal organs of animals examined a few hours after death. They used in their experimental work rabbits, guinea pigs, dogs, cats, lambs, and calves. It may be briefly stated with reference to this work, that no well marked cases resulting in death were developed, although certain symptoms and lesions similar to those in animals naturally affected with milksickness were produced. In concluding their report, they assert that "taken as a whole, the facts do not indicate that a specific microorganism is the cause of milksickness or trembles. The bacillus in question belongs to a group which seems widely distributed and for the most part certainly not endowed with pathogenic qualities."

Luckhardt (1909) made further studies in the laboratories of Drs. Jordan and Harris on the physiology of Bacillus lactimorbi, on its distribution, and on its pathogenicity. He isolated the organism from alfalfa from farms in Wisconsin, Illinois, and Indiana, which supplied certified milk to Chicago and Milwaukee, and from four species of weeds, Bigelovia Rusbyi, Solanum elæagnifolium, Gutierrizia sphærocephala and Portulaca pilosa from the Pecos Valley, New Mexico. He furthermore isolated it twice from Roquefort cheese. Dogs were used in inoculation experiments. In discussing the results of this work the author concludes that "the preceding experiments are far from being decisive in establishing B. lactimorbi as the etiological factor in the production of milksickness. The organism either loses its pathogenicity very rapidly when grown on artificial media, or the virulence of the

organism is dependent upon what may be termed a symbiotic life or existence on certain plants. . . . On the other hand, it is remarkable that if B. lactimorbi be the cause of milksickness, it should have so wide a distribution in milksick and nonmilksick regions."

In a few cases certain molds and mushrooms have been claimed to be etiological factors. Among those who suggest that mushrooms are the poisonous agent are Winans (1840), Johnson (1866), and Gardner (1880). Hessler (1905) reports the finding of Sterigmatocystis, one of the cosmopolitan molds, in the blood of an affected heifer. Slack (1854) compared milksickness to ergot poisoning and believed the cause to be a "fungus production" on grass or grass seeds, a view also held by Nagle (1859).

Several other more or less fanciful causes of milksickness which cannot be classified under either of the three groups of causes have advocates within North Carolina and will, therefore, be briefly treated before giving consideration to the poisonous plant theory. Walker (1886) experimentally exposed corn fodder to the dew in a milksick cove and thus communicated trembles to a yearling. Farmers in some sections of North Carolina have come to believe that cattle which are penned up at night and not permitted to graze before the dew has evaporated are not liable to contract the disease. This same opinion has been expressed in the writings of Evans (1860), Reagan (1884), and Walker (1886). The influence of dew is only an apparent one as explained, in part at least, by Woodfin (1878), who says that cattle which are confined at night cannot range sufficiently far to reach the affected and usually remote tracts of land. The influence of dew is explained by Davis (1881) on the ground that animals eat more greedily of plants wet with dew than when they are dry.

A number of writers have adhered to the idea that the disease is produced by a gas or miasm rising from the earth. Lea (1821), Horne (1846), Jones (1862), and Wozencraft (1873) employ such terms as "an exhalation from the soil" and "peculiar miasma" in accounting for the disorder.

The claim has furthermore been made by Lescher (1850), Thompson (1853), Rawlings (1874), Dorsey (1876), and Sale (1871) that the disease resembles, in some respects, malaria.

Two accounts, Kennedy (1878) and Achelor (1884), which have come to hand, attribute the disease to the bites of a certain fly, an idea which would liken milksickness to the tsetse-fly disease or sleeping sickness in Africa. This idea is vigorously opposed, however, by the writings of Carpender (1884) and Murfin (1884).

c. Poisonous Plant Theory

Many physicians and laymen have held to the theory that trembles is caused by the ingestion of a poisonous plant. One reason for this view is the general accord of observations to the effect that "milk sick" tracts are no longer able to communicate the disease after the natural vegetation has been replaced by cultivated plants. Bennett (1822) is among the earliest writers to record this fact. He states that "those farmers who keep their cattle and horses in enclosed pastures which have been cultivated do not lose them by this disease." This opinion is also in accord with the writings of Crook (1857) and Simon (1888). Pickard (1857) cites an interesting example which substantiates the view that clearing and cultivation are efficacious in destroying the dangerous quality of milksick lands. He reports that a "family having suffered from its ravages, plowed up a pasture field, digged around the stumps, thoroughly turning all the soil, and sowed the field in grass, upon which they have kept their stock for twenty years, and at no time has milksickness made its appearance; while on other portions of the farm, uncultivated, it is as fatal as ever." The same opinion is expressed by Drake (1841), who records that "clearing and cultivation, even girdling the trees, harrowing the ground, and sowing it with grass seed destroys and renders inactive the cause, whatever it may be."

Another reason for belief in poisonous plants as the cause of trembles, is that the disease is largely limited to the season when animals are allowed to graze. That the disease may occasionally appear in winter is attested by the writings of Yandell (1852), Beck (1857), Waggoner (1859), Beach (1884), and Shapard (1892). This may be accounted for by the feeding of hay as has been recorded by Gray (1881), Beach (1883), and others. The latter makes the following interesting statement: "That cattle *may* have trembles in the winter season is a matter of occasional observation, and the old citizens generally attribute it to the feeding of cattle upon wild or swamp hay." Beck (1857) has stated that in Kentucky the disease is prevalent only in winter, whereas, in Indiana it occurs in all of the other seasons.

It seems to be the common belief among farmers in North Carolina that the usual time of prevalence is during the months of August, September, October, and November. Dawson (1842), Rawlings (1874), and Shapard (1892) refer to the greater prevalence of trembles in late summer and autumn. Dewey (1845) speaks of its disappearance after the first hard frost. While the autumnal incidence has been found to be most frequent, it may also occur during spring and early summer. An epidemic in Tennessee recorded by McCoy (1907), to which refer-

ence has previously been made, occurred during April and May. In the light of evidence to be presented later in this paper, there is no reason for believing that the disease may be limited to any one season. If it chances to be more prevalent in late summer and fall, as is commonly believed in this State, it can be accounted for by the refusal of animals to eat of the weed until this season of the year. A scarcity of more palatable plants through drought may compel them to eat more freely at this season of white snakeroot than is their custom.

A considerable number of flowering plants have at various times been held to be the cause of trembles. Among them are the following: Rhus toxicodendron (poison ivy), Eupatorium urticaefolium (white snakeroot), Lobelia inflata (Indian tobacco), Cicuta maculata (water hemlock), Bigelovia Rusbyi (rayless goldenrod), Psedera quinquefolia (Virginia creeper), Symphoricarpos orbiculatus (coral berry), Apocynum cannabinum (Indian hemp), Caltha palustris (marsh marigold), Euphorbia esula (leafy spurge), and Aethusa cynapium (fool's parsley). Through the writings of Drake (1836 and 1841), Travis (1840), Crook (1857), Chase (1861), and Elder (1874), poison ivy was at one time quite generally accredited as being the cause of the disorder. Henry (1854) and Beach (1883) pointed out that horses, cattle, and sheep frequently eat the foliage of this plant with manifestly no ill effects. The connection of poison ivy with trembles is further opposed by Landrum (1861) and H. M. K—— (1862), who assert that milksickness has never occurred in certain localities where poison ivy grows luxuriantly.

Claims that a number of other plants are the probable cause may be found in the accounts of McCall (1822), Short (1840), Fisher and Kennicott (1861), and Allen (1878), but these authors adduce little evidence in support of their conclusions.

White snakeroot has probably been more commonly accused of being responsible for trembles than any other plant. As long ago as 1840 Dr. Barbee, who will be recalled as having first given information to Dr. Drake which led to the publication of the first account of the disease, expressed the opinion that this weed was the cause of the disease. A few years later Dewey (1854) stated that the disease is due to "a succulent plant bearing a white blossom." He did not know the name of the plant and failed to have it identified, but it is very probable that he had reference to white snakeroot. Subsequently, evidence adduced by feeding experiments conducted by Vermilya (1858), Jerry (1867), Townshend (1883), and Moseley (1906) point to white snakeroot as the etiological factor in the production of milksickness.

Moseley's account, beyond doubt, contains the best experimental evidence which had been presented up to that time on the poisonous properties of this weed. His results were not entirely convincing, however, since Crawford (1908), in criticising them, states: "It cannot be said that Moseley has even proved Eupatorium urticæfolium to be a poisonous plant, much less the cause of "trembles." Beach (1883) had previously recorded the observation that cattle frequently eat this weed without any apparent ill effects.

The most extensive recent studies, except those published in a preliminary report from this Station (1917), bearing on the toxicity of white snakeroot are those of Crawford (1908), which were undertaken because of an outbreak of trembles resulting in the death of about 50 head of cattle near Minooka, Ill. Patches of white snakeroot which had been browsed were found in pastures where the animals had contracted the disease. Some of these weeds were collected and dried, while others were preserved in water to which a small quantity of chloroform had been added. Aqueous extracts were then prepared and fed or injected subcutaneously into rabbits, cats, and dogs No cases of trembles developed in these animals and Crawford became so convinced of the innocuous nature of the plant that he took without ill effect a water extract from 400 grams of fresh Eupatorium urticæfolium. These results with aqueous extracts are in accord with those secured by the present writers, and which are discussed later in this report.

Crawford furthermore reports that he fed 58 grams (about one-eighth pound) of fresh plant to a lamb weighing 25 kilograms (about 55 pounds) with the production merely of some diarrheal symptoms. In criticising this experiment, Moseley (1909) says that this quantity would probably not be fatal to a full grown rabbit. In his summary of these experiments, Crawford states "It cannot be said that it has been proved that milksickness is due to any constituent of Eupatorium urticæfolium."

The preliminary account referred to above contains the results of feeding white snakeroot to sheep during the season of 1916. Since the present season's work has been in part a confirmation of that of 1916, it is deemed best to combine all of the data bearing on any phase of the problem. These data will, therefore, appropriately appear later in this report.

Distribution and Description of White Snakeroot.

White snakeroot is a member of the composite family and belongs to a genus which is represented in the southern United States by about

forty species. The plant is also known by the common names white sanicle and rich weed, and bears the technical name Eupatorium urticæfolium Reich., which is synonymous with E. ageratoides L. f. and E. boreale Greene. The specific name indicates that the leaves resemble in appearance those of the wood nettle. This plant (Plate 1) grows in rich woods bordering streams, being confined to rather low, swampy situations, or within shaded mountain coves, particularly on northern slopes. It often grows so luxuriantly in these latter situations within North Carolina as to become the principal vegetation on the forest floor.

It is evidently very widely distributed since its range is said to extend from New Brunswick southward to Florida, Georgia, and Louisiana, and westward to Nebraska and Oklahoma.

Specimens in the herbarium of the New York Botanical Garden* show that it has been collected in Ontario, Maine, Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, District of Columbia, Virginia, West Virginia, Georgia, Louisiana, Michigan, Illinois, Indiana, Minnesota, Iowa, Nebraska, Oklahoma, and Kentucky. This would indicate that it very probably occurs in all of the other States east of the Mississippi river as could best be ascertained by examinations of the Gray Herbarium at Harvard University and of the United States National Museum.

The plant is perennial rooted, varies in height from one to five feet, and is more or less branched. The leaves are three to six inches long, opposite, long stalked, and thin. They are ovate or slightly cordate in outline, are pointed, and the leaf margin is coarsely and sharply serrate. The base of the leaf is cordate or is abruptly narrowed into a long, slender petiole or stalk. Furthermore, the leaves are strongly three-ribbed. The flowers open from July to November, and are very attractive since they are clustered in snowy white, compound corymbs. The involucre is narrowly bell-shaped or campanulate, being composed of linear, acute bracts. The achenes or seeds are smooth.

The plants are for the most part smooth, but some possess a coating of hairs. To those which are distinctly hairy, the appropriate varietal name villicaule is applied by some. Intergrading forms between the smooth and hairy forms may be found in any area where this plant occurs.

*This information was furnished through the kindness of Mr. Percy Wilson of the New York Botanical Garden, to whom thanks are hereby extended.

Comparison of White Snakeroot with Related Species

Some of the species of Eupatorium are distinguished with difficulty from white snakeroot, which accounts for the fact that farmers on being shown white snakeroot and told that it is the cause of trembles, not infrequently assert that their stock feed upon the plant without any ill effects. The casual observer cannot depend upon the color of the flowers to distinguish species, since more than thirty species of Eupatorium have white flowers. Furthermore, Eupatorium incarnatum, which may have flowers tinged with pink or purple although frequently they are white, is practically indistinguishable from white snakeroot except by the presence of minute hairs on the corolla tube. These can be seen only with the aid of a hand lens.

Twenty-nine species with opposite leaves have been described. Only seven of these, however, including white snakeroot, have manifestly stalked or petioled leaves. In this group five possess leaf blades which are similar in shape to those of white snakeroot. The leaf blades of the other one are fully twice as long as broad, which makes its separation easily possible.

Whether or not the roots are perennial is a distinguishing character, since only five species with perennial roots, in which group white snakeroot is included, have been listed. Two of these are shrubby and the other three are herbaceous. In the latter group, the character of the leaf margin, whether it be provided with sharp or blunt teeth, is used in separating E. urticæfolium from E. aromaticum, and the absence of a beard on the corollas separates these two species from the other, E. incarnatum.

The direction of attention to these points of similarity between white snakeroot and other species of Eupatorium will, it is hoped, serve to indicate that careful observation and experience are necessary in determining whether one is dealing with white snakeroot or some of the other species which are not known to be poisonous, but which are commonly present within the State.

Names of the Disease

This disease has been appropriately designated as trembles in animals, because trembling is the most obvious symptom, and as milksickness in man, because it may be communicated to man through milk from cows affected with trembles. It has been given a number of other names, but it is not possible because of the mystery which has for so long surrounded the cause of the malady to determine whether, in every instance, reference is made to the same disorder.

Since obstinate vomiting is such a prominent symptom of the disease in man, physicians and others have very commonly employed the name sick stomach, Beck (1822), Bennett (1822), Campbell (1881), Chamberlain (1826), Crookshank (1826), Drake (1836), Drake and Yandell (1840, 1841, 1842), Haines (1822), McCall (1830), Wright and Bennett (1827), and Yandell (1832).

The name "tires and slows," employed by Howard (1871), Logan (1849), and Byford (1855) are used in some sections. Jordan and Harris (1909) are of the opinion that "alkali poisoning" of western Texas and New Mexico is identical with trembles or milksickness in States east of the Mississippi River. Other names, which have at one time or another been employed but which have not been generally used, are swampsickness, river fever, puking fever, stiff-joints, colica trementia, morbeo lacteo, ergodeleteria, gastritis, gastro-enteritis, mukosoma, syro, lacemesis, caconemia, and paralysis intestinalis.

CLINICAL HISTORY

Symptoms

The published reports of observations by others are essentially unanimous in stating that horses and cattle are both very subject to the disease. Sheep and goats may furthermore be affected and a number of writers have asserted that hogs are susceptible. McCall (1822), Coleman (1822), Drake (1840), Winans (1840), and Davis (1881) are among those who claim that hogs are subject to the disease. Some writers have claimed that hogs are at most only rarely affected—Woodfin (1878) and Johnson (1866). It has been stated, too, that deer may suffer from the disease, and that other wild animals, such as wolves, foxes, buzzards, vultures, and crows may contract trembles by feeding upon carcasses of animals which have died of this disease.

a. In Cattle.—The symptoms of trembles among domestic animals have been described with no great degree of fullness except in cattle. The following account is substantially a concensus of all who have observed the malady. The first sign of the disease is indicated by a listlessness and disinclination to move. In his memoir, Drake (1841) has well characterized the initiation of trembles by stating that "the animal begins to mope and droop, to walk slower than its fellows, to falter in its gait." Practically all accounts record the exhibition at this stage of muscular weakness and of trembling, especially when the animal is driven. Such animals, too, are generally constipated. Some few writers record that cattle in this stage are greatly excited and are disposed to fight; this is not mentioned, however, by the great majority

of observers. When the disease has progressed sufficiently so that the characteristic trembling ensues, there is a marked stiffness of the joints. The animal may sink to the ground manifesting great weakness and exhaustion, and may remain lying for hours or days on the spot where it has fallen. Animals in this stage may recover, but more often die.

One peculiar feature of the disease, *i. e.,* that violent exercise has much to do with the development of acute symptoms, has been generally reported and is in accord with statements by a considerable number of farmers within the State. Prospective buyers of cattle from "milksick" areas make use of this fact and drive the cattle until they are heated before deciding whether it is safe to purchase. Dixson (1833) early noted this and says "It is one of the peculiarities of the disease that the poison lies long dormant in the system, and only becomes active when excited by some indiscretion or violent bodily exertion." Woodfin (1873) states that "beeves have been fattened in these infected localities, started to be driven to market, take the trembles and fail the first or second day, while other cattle feeding on the same grounds, left at home, remain healthy."

This is entirely in accord with observations made by Mr. W. R. Radford and Mr. James Phillips in Mitchell County, at Spruce Pine, N. C., during the present year. Mr. Phillips purchased a herd of 20 steers and heifers which had pastured in Wiggins' Cove, on the farm of Mr. S. T. Henry, where white snakeroot grows profusely. The animals were driven to the shipping station, several miles distant, and upon arrival at the station five began to tremble. They remained lying down most of the time for several succeeding days, and when made to rise would stagger along for a short distance and then fall suddenly. They had all apparently recovered, however, after about a week.

The belief, which prevails in some sections, in the occurrence of the disease in the autumn only, may be accounted for in the light of this peculiar fact, if it is kept in mind that in these places it is the practice to drive cattle to market at this season of the year.

Another peculiarity which has been recorded by a number of observers is that the breath of affected animals has a foul odor. This has been described as "garlicky," "like chloroform liniment," and "mildly like acetone." Elder (1874) speaks of it as a "singular fetid odor, pungent, and corrosive."

The fact that not all cattle in the herd become affected has always been a disturbing factor in accounting for the cause of trembles. As long ago as 1822, Coleman notes that "Cattle and horses do not always become afflicted with the disease if allowed to range in woods where the disease is common." Woodfin's (1878) comments bearing on this point,

if judged in the light of experiments with sheep to be presented later, are equally true and interesting. He says: "Many animals may feed on the same lands and evidently partake about equally of the poison and some of them suffer violently and die; others suffer lightly and recover, and others still, perhaps the larger number, remain quite healthy."

b. In Sheep.—Very little that is distinctive can be gathered from the published accounts of the symptoms of the disease in other domestic animals. Writers have largely resorted to the use of the expression "similar to those of the disease in cattle" in describing the symptoms.

The only clinical account of the disease in sheep which has come to our attention is that given by Jordan and Harris (1909) from observations made by D. D. Todd upon two ten weeks' old lambs. Both of these animals were lying down when found, and one made no attempt to rise, while the other kept its feet going in a walking motion with each unsuccessful effort to get up. Respiration was regular in both animals but forced and jerky in the case of one lamb. No sign of pain was evident, but occasionally one animal ground its teeth.

In the present studies in sheep considerable individual variation has been found to exist, both in the period elapsing until the initial symptoms of trembles are apparent and in the period following until death ensues. During the season of 1916 some were sick as early as three days after being placed on the experiment, and no ill effects were apparent for three weeks in other cases. During the present season (1917) one animal became sick on the second day and died within forty-eight hours after feeding was begun. Others remained apparently normal for about twelve weeks before contracting the disease. Sheep usually live three or four days after the disorder is first noticed, but some have been observed to die within twelve hours. Only one sheep characteristically affected entirely recovered and the feeding of white snakeroot to this animal was discontinued as soon as trembling was noted.

One of the first signs of the onset of the disease is a loss of appetite and gritting of the teeth. Such animals are sluggish and manifest a marked disinclination to move. They may remain standing in a droopy posture (Fig. A) or may be quiet in a normal resting position. Respirations are accelerated, often jerky and somewhat labored. A marked stiffness of the legs and ataxia characterize the movements in walking. This is manifest early and becomes more aggravated as the disease progresses. If after a day or two, the animal is urged to rise and is driven a few yards, muscular spasm, especially in the limbs, is evident. The sheep then refuses to move, stands with hind limbs placed well under the body (Figs. A and B) and all feet spread apart laterally. In this

posture, the back is bowed, the neck outstretched and the head lowered. Within a few seconds, the quivering spreads from the limbs over the entire body, increases in intensity, and becomes a violent, involitional tremor (Fig. B). This is accompanied by slight, intermittent, tetanic contractions of the musculature of the limbs. At this stage of trembling ataxia is very pronounced, and the animal is unable to stand (Fig. C). It drops quickly into the normal resting posture (Fig D) or assumes a characteristic position, in which the head and neck are outstretched and the jaw is resting upon the ground (Fig. E), whereupon the trembling apparently immediately ceases. If the sheep is made to rise after it has lain down for a few moments, a second and more violent spasm of trembling ensues with a repetition of the symptoms as described. Trembling may recur repeatedly every time the animal is made to rise. The quiescent period is shortened, however, after each spasm of trembling and may begin as soon as the animal is placed on its feet. Even after the disease has progressed to the point where trembling is violent, many animals still possess considerable appetite.

After the second or third day, the animal becomes comatose and may lie prostrate on its side (Fig. F) until death occurs. There is generally a very considerable decrease in weight, most of which occurs during the two or three days preceding death. The feces generally remain normal, with, in some cases, a small amount of mucus. Urination is more frequent than in healthy animals and only a small quantity is voided each time. Vomiting occurred in the case of two animals under observation, and a frothy discharge from the nostrils is not uncommon after coma sets in.

c. In Hogs.—The symptoms of trembles as observed in hogs are in general like those in sheep. There is first a listlessness, not accompanied, however, by any marked loss of appetite. The animal remains lying unless urged to rise, or unless food is offered, whereupon it stands with hind feet placed well under the body. In this position, the head droops, the eyes are partially closed, and the back is bowed. (Fig. I.) There is no lack of coordination of movement in walking for the first few days, although the hind legs are markedly stiff. Later, this stiffness appears in the fore limbs. After the pig has stood for a few minutes while eating at the trough or is driven around in the pen a slight quivering in the legs begins. Within a few moments, the trembling has become progressively more severe, has spread over the entire body and becomes a violent shaking or tremor, so acute that the animal squeals, presumably with pain, in its efforts to remain on its feet. At this stage of trembling the animal either falls to its knees or sits upon its haunches (Fig. J). From this position, after a moment, it falls into

the resting position (shown in Fig. K), in which the feet are folded under the body and the jaw resting upon the ground, or it falls prostrate on its side with legs outstretched (Fig. L). Trembling continues for some little time after the animal has lain down.

Three or four days after trembling is first noted, it is not uncommon for the animal to topple from a standing posture to one flat upon its side. Coma appears in the 24 or 48 hours preceding dissolution.

d. In Guinea Pigs.—The disease is first apparent in guinea pigs by their refusal to eat. They are less active than unaffected animals and crouch in a corner of the cage. The hair upon the head and neck of sick animals does not lie down smoothly and their eyes remain only partially open. When such an animal is disturbed, it walks with the back arched. As the disease progresses, they become more listless, refuse all food, and become emaciated in consequence. Commonly diarrheal symptoms are present. Muscular tremors occur, but are not easily apparent since the animals cannot be made to stand nor to walk. Finally stupor sets in, at which stage they are very limp, with insufficient control of their limbs to enable them to rise when placed on their side. The half-closed eyes and general debility as indicated by the droop of the ear and posture are shown in a comatose animal in Fig. H.

e. In Man.—Several excellent descriptions of milksickness in man have appeared, in all of which the symptomatology appears to accord fairly uniformly. In the accounts of Coleman (1822), Graff (1841), Byford (1855), and Way (1893), attention is directed to the most typical symptom, "sick stomach."

The onset of the disease is gradual, and after a day or two of weakness and debility, accompanied by loss of appetite, the patient is seized with epigastric distress. Excessive vomiting follows, the bowels are obstinately constipated, and there is always great thirst, although the water taken is vomited immediately. Abdominal pain is generally present, although some writers record an absence of distress in this region, and muscular tremors are generally present. The breath acquires a peculiar foul odor, a characteristic which some regard as of great diagnostic value, since they maintain that it can be detected immediately upon entering the patient's room. The tongue is swollen. Respiration is normal and temperature is usually subnormal, ranging from 97 to 98 degrees F., although McCall (1822), Simon (1875) and a few others state that fever exists. If the disease is severe, symptoms of typhoid may appear. The patient may become delirious, but in fatal cases a period of coma precedes dissolution. In such cases, death may come as early as two days after the onset of symptoms or may be deferred for two or three weeks. Lasting debility appears to be a common sequel

of the disease. Those who have recovered are usually incapacitated for hard work especially during warm weather. The writers themselves have never seen a person suffering from milksickness, but conversations and correspondence with doctors who have treated cases, and with persons who have recovered from an attack, indicates that the preceding account of symptoms describes the disease.

Mortality in Trembles or Milksickness

No data are available from which even an approximation of the fatalities among domestic animals can be made. One writer has estimated that 5,000 animals have died from the disease in a certain area in northern Ohio. The outbreak near Minooka, Ill., which occasioned the investigations of Crawford (1908), previously referred to, resulted in the death of about fifty cattle. Mr. H. E. Crawford, Shooting Creek, N. C., reports the loss of hundreds of dollars worth of horses, cattle, sheep, and hogs, and that in almost every case affected animals succumbed.† In a flock of sheep which came under the observation of Mr. George Evans, Sheep Field Specialist at this Station, seven animals in a flock of eight died. In our feeding experiments with sheep, only one individual characteristically affected recovered among a total of thirty-one animals. In the succeeding year this animal was again used in feeding experiments and contracted the disease and died. All accounts which have come to hand, both published and verbal, indicate that relatively few animals recover from a prolonged attack of trembles.

The data on the mortality in man from milksickness are by no means complete and considerable differences of opinion are found to exist in published reports. Coleman (1822) reports the loss of "about one case in twenty or thirty," and Collins (1902) "about 40 per cent of my cases." Dr. J. E. Wilson, Canton, N. C., informs us that he has treated many cases without the loss of one.

Jordan and Harris (1909) have prepared a tabulation of all published reports in which the number of cases and deaths is specifically stated. This tabulation will emphasize the variation which has been mentioned and will give at least an approximation of the average mortality. It will, therefore, be quoted *in toto,* and to it will be added the record of fifty-six cases and eleven deaths which either came under the observation of Jordan and Harris or were reported to them during their investigation of this disease, and of two deaths at Losantville, Indiana, in 1916.*

†From a letter by Mr. E. S. Millsaps, County Agent, Clay County.
*From a letter by Dr. N. F. Canady, Hagerstown, Indiana.

Cases	*Deaths*	*Authority*
4	2	Lewis (1829)
10	5	Carney (1847)
1	0	McNutt (1857)
49	26	Sale (1871)
50	7	Smith (1867)
30	0	Smith (1874)
3	2	Houser (1880)
22	4	Spalding (1881)
3	1	Gray (1881)
4	2	Simon (1888)
11	6	Pusey (1880)
6	5	Graff (1841)
9	5	Tuller (1889)
2	0	Scott (1889)
6	1	Hurd (1875)
13	2	Sykes (1891)
6	1	Lyday (1896)
9	1	Mich. S. B. H. (1897)
5	2	Collins (1902)
13	6	Palmer (1904)
6	6	McCoy (1907)
56	11	Jordan and Harris (1909)
2	2	Canaday (1916)
320	77	

The mortality in man as judged by these data is seen to be approximately 24 per cent.

EXPERIMENTAL PROCEDURE

Since white snakeroot does not grow in the vicinity of Raleigh, N. C., where these feeding experiments were conducted, it was arranged to secure daily shipments of the green weed from Shooting Creek, N. C., where this plant grows luxuriantly. Since this town is over 400 miles distant from Raleigh, the weed used had been collected about 48 hours prior to its arrival at Raleigh. The weed was fed twice daily along with a maintenance ration of some dry concentrate. In the feeding experiments of the present season (1917) this feed was further supplemented by timothy hay. The sheep were kept singly in small pens in a sheep barn. A litter of shavings covered the concrete floors. The animals used were selected from a flock of grade ewes and their lambs, all of which were in a healthy condition, and, with the exception of those used in the experiments, remained so. No case of trembles or milksickness had ever appeared in this or any other of the Station flocks prior to the initiation of these experiments and none developed

during the course of these experiments except in animals under experimentation. The flock number of each individual was retained and is used subsequently in reporting the experiments with the several animals.

At first the grain and weed were fed separately; but since the animals either avoided eating any of the weed or ate only sparingly of it, the weed was passed through an ensilage cutter and then mixed with grain before being fed. A daily account was kept of all of the feed which was refused by each animal, and these data were employed in approximating the total amount consumed during the course of the experiment. Since the weed and grain were mixed, and since some loss of weight was due to desiccation, the quantity of snakeroot eaten by each animal could only be approximated.

In the experiments with suckling lambs, the ewes and their lambs were kept separated except while the lambs took their milk. The ewes at these times were put into the pens with the lambs, so that the lambs never had access to white snakeroot, as would have been the case had the lambs been permitted in the ewes' pens.

Before feeding the weed to pigs, which were confined in pens in the sheep barn, it was passed through an ensilage cutter and mixed with cracked corn and shorts.

The dogs, which were fed upon the carcasses of sheep dead of trembles, were confined in pens and given, in addition, dog biscuits and refuse from the kitchen.

The guinea pigs which were used in these experiments had never been used in experimental work and were consequently entirely normal. During the experimentation they were kept in cages especially constructed for housing small animals, and were given a diet consisting of a mixture of cracked corn, wheat, oats, and rye, which was supplemented by green grass and clover. All animals used in any one of the experiments to be subsequently reported were kept together in the same cage. Each group of animals could thus conveniently be fed twice or three times daily with white snakeroot or some of the products prepared from this plant.

The material extracted by boiling the plant in water, in 2 to 3 per cent hydrochloric acid, or alcohol, for twenty-four to forty-eight hours, was evaporated to dryness on a water bath, ground into powder, and placed in No. 2 Lilly New Process Gelatine Capsules. The desiccation of these products necessitated heating for a long time because of the resinous nature of the extracted material.

The animals were held while feeding them these capsules, and were given from six to twelve capsules daily. By the exercise of considerable patience, the guinea pigs could be made to masticate and swallow the

capsule and its contents. This method of administering the products of white snakeroot was abandoned for a more convenient one in the other experiments. All materials not already in liquid form were dissolved in water and were allowed to drop from a pipette into the guinea pigs' mouths.

In expressing the sap or juice from white snakeroot, use was made of a small meat chopper. The green weeds were passed through this meat chopper which had been fitted with a plate having small openings. The rotation of the cylinder which fed the machine pressed the macerated weeds through these small openings and at the same time pressed out the plant sap. The sap escaped through the crevice between the rotating cylinder and the frame of the chopper, that is, in the direction opposite that in which the "pomace" or residue escaped.

Post-mortem examinations were made of twenty-two of the thirty-one sheep which died of the disease. Thirty of these animals were observed to tremble in the characteristic manner. With the exception of ewe No. 169 and lamb No. 237, both of which had stomach worms (Hemonchus contortus), there was no evidence that death resulted from causes other than the feeding of E. urticæfolium. Both of these animals manifested characteristic symptoms of trembles, however. Post-mortem examinations were furthermore made of all other animals which died during the course of the experimentation and certain of the internal organs were also preserved for microscopic study. A detailed report covering studies on some of these tissues has been prepared and is representative of all cases examined.

RESULTS OF EXPERIMENTS

a. With Sheep

Experiment 1.—Three ewes, Nos. 11, 26, and 10, were used in Experiment 1, a preliminary experiment which was designed to determine whether harmful effects follow the feeding of E. urticæfolium. This experiment was begun on June 17 and closed on August 2. However, from June 22 to July 6 and from July 18 to July 28, it was impossible to secure the weed. During these periods the animals were grazed on Bermuda grass pasture. Except during the two periods mentioned, a liberal supply of white snakeroot was fed just as it arrived from the point of shipment. In addition, a maintenance ration of grain was fed in a separate trough. Neither the weeds nor the grain were weighed in this experiment. Initial and final weights of each animal were recorded.

In the period between June 17 and July 16, ewe 11 was fed on white snakeroot and grain for an aggregate of fifteen days. A typical case

of trembles had developed by July 16, and death occurred two days later. Food was refused during these two days, and there was a decrease in weight from 102 to 77 pounds during the 29 days of intermittent feeding.

Ewe 26 was given a ration of snakeroot and grain for 22 days, between June 17 and August 2. No symptoms of trembles developed during this period. The initial weight of this animal was 91 pounds and the weight at the time the experiment was discontinued was 74 pounds.

The control ewe (No. 10) was maintained on pasture alone from June 17 to July 28. On July 28 she was put in a pen and was given a ration of white snakeroot and grain until her death, which occurred on August 2. This ewe trembled only slightly, was very weak and emaciated, and lost 20 pounds during the experiment. Although the symptoms were not as marked in this case as in ewe 11, yet all conditions indicated that death was due to trembles.

Experiment 2.—Three ewes, Nos. 14, 23, and 26, were employed in Experiment 2. This experiment was planned to confirm the results secured in Experiment 1. Since the animals used in Experiment 1 had refused to eat any considerable quantity of snakeroot when it was fed separately, it was decided to pass the weed through an ensilage cutter and mix it with an equal quantity of weight of grain. One pound of this mixed feed was given each animal twice daily.

On the sixth day after ewe 14 was placed on the experiment she had developed trembles and died on the following day. Her initial weight was 80 pounds and her weight at death was 73 pounds.

The first symptom of trembles in the case of ewe 23 was noted 19 days after the experiment was begun. A well-defined case of trembles developed in this animal, and she died six days after the first symptoms were noticed. Her weight when feeding was begun was 70 pounds, and there was a loss in weight of 8 pounds during the 25 days.

Since ewe 26 had shown no ill effects from the feeding of white snakeroot in Experiment 1, she was used in this experiment. It will be recalled that the weed was fed separately and was not ground in the first experiment. Ewe 26 had eaten only sparingly of the weed in this experiment. However, after 16 days feeding with the mixed ration, a very typical case of trembles developed. The feeding of the weed was therefore discontinued and she was put on pasture.

Experiment 3.—In this experiment, ewes 12, 7, 29, 27, and 19 were fed the mixed ration to determine the amount of weed and the length of time required to develop trembles. Table 1 shows clearly the variation that exists with reference to these two points.

TABLE I—RESULTS OF FEEDING WHITE SNAKEROOT TO SHEEP IN 1916. EXPERIMENT 3.

Ewe No.	*Initial weight.*	*Experiment begun.*	*Feeding discontinued.*	*Days before death occurred.*	*Weight at death.*	*Feed consumed*	
						Grain	*Weed*
	Pounds.				*Pounds*	*Pounds.*	*Pounds.*
12	74	August 5	August 18	13*	....	5.5	11.5
7	86	August 5	September 1	27	61	13	9
29	81	August 5	August 21	16	55	8	10
27	70	August 5	August 10	5	56	2.25	4.5
19	113	August 5	August 23	18	89	8	11.25

*Feeding discontinued after thirteen days.

Ewe 12 was taken off the experiment on August 18, at which time she was affected with trembles. She had lost only 1 pound during these 13 days. It will be noted that the amount of weed required to cause trembles in these five animals varied from 4½ to 11½ pounds and the range in time from 5 to 27 days.

Experiment 4.—In order to determine whether or not trembles is infectious, ewes 26 and 12 were put in a small Bermuda grass lot on August 18. Two healthy ewes from the flock were put in the same lot and all were fed grain in the same trough. It will be recalled that both ewe 26 and ewe 12 had typical cases of trembles when their feeding in experiments 2 and 3, respectively, were discontinued. Ewe 26 died on August 19 and ewe 12 still trembled a week afterward. However, she finally recovered fully. Neither of the other two ewes had developed any symptom of trembles when the experiment was discontinued on September 4, and both subsequently remained normal. It is realized that this indirect evidence of the relationship of a specific infection is in itself not convincing so that in studies to be subsequently reported an effort was made to isolate an organism from the internal organs of affected animals.

Experiment 5.—This experiment was designed to determine the length of time that white snakeroot must be fed to sheep when, after a certain number of days the usual grain ration and pasturage are given. Two animals were therefore fed for three days on a mixture of equal parts of ground weed and grain and were then put on pasture. Two others were fed for six days before being placed on pasture and two others for nine days, after which they were put on pasture. Table II contains the essential facts in this experiment.

TABLE II—RESULTS OF FEEDING WHITE SNAKEROOT TO SHEEP IN 1916. EXPERIMENT 5.

Ewe No.	*Initial weight. Pounds.*	*Final weight. Pounds.*	*Days on experiment.*	*Feed consumed.*	
				Grain.	*Weed.*
169	83	78	3	1.5	1.5
171	85	80	3	1.5	1.5
162	96	82	6	5.5	5.5
168	89	79	6	4.25	4.25
161	102	62	9	6.75	6.75
170	105	92	9	5.5	5.5

Ill effects followed only in the cases of ewes 169 and 161, the former dying 8 days and the latter 11 days after being taken off the experiment. Since ewe 169 evidenced no well marked symptoms of trembles, a post-mortem examination was made which showed that stomach worms may have been a contributory cause of her death. Ewe 161, however, developed a typical case of trembles and is the animal represented in figures A, B, C, and D.

Experiment 6.—The preceding experiments, which were conducted in 1916, had demonstrated the poisonous nature of white snakeroot. Attention was therefore first directed in the succeeding year to determine by experiment, first, if the disease can affect animals in lactation, and second, if these animals can transmit the disease through the milk to their offspring. For this purpose, six ewes with suckling lambs were employed in an experiment which was begun May 13, 1917. The facts brought out in the second part of this experiment are properly referred to Table VI and will, therefore, appear in their appropriate place later in this report. The data bearing on the first point, however, are summarized in Table III, which is presented as follows:

TABLE III—RESULTS OF FEEDING WHITE SNAKEROOT IN 1917 TO EWES WITH SUCKLING LAMBS. EXPERIMENT 6.

Ewe No.	*Initial weight. Lbs.*	*Experiment begun.*	*Date of death.*	*Days before death occurred.*	*Weight at death. Lbs.*	*Gain or loss. Lbs.*	*Feed given.*			
							Grain. Lbs.	*Weed. Lbs.*	*Kale. Lbs.*	*Hay Lbs.*
171	76	May 13	Aug. 30	109	88	12	162	54	134	106
162	81	May 13	Sept. 2*	111	88	7	163	55	134	108
175	83	May 13	Sept. 2	111	98	15	165	55	134	108
167	104	May 13	Aug. 20	99	105	1	132	44	132	96
12	94	May 13	July 24	72	97	3	103	34	134	69
168	80	May 13	July 15	63	74	6	80	27	124	60

*Discontinued feeding white snakeroot at this date.

It will be noted that four of the six ewes developed trembles and died while on this experiment, and that two were apparently normal when the feeding with white snakeroot was discontinued. Only meagre quantities of milk were being given by these animals after July 1. Ewes 168 and 12 died on July 15 and July 24, respectively, at which times their

lambs were still alive. Ewe 167, which died August 20, had not suckled her lamb since July 25, and Ewe 171, which died August 30, had not suckled her lamb since June 15.

It should further be noted in this experiment, as well as in experiments 7 and 8 which follow, that the figures representing the quantity of weed given do not represent the quantity actually eaten, since the ewes consistently attempted to avoid eating any of the white snakeroot. Very much smaller amounts would have produced death, had they eaten as much as a pound daily for several days. It is furthermore believed that the liberal quantities of grain, kale, and hay which were given to stimulate the flow of milk, perhaps by absorbing the toxic principle, rendered it less active.

Experiment 7.—It was planned in this experiment to duplicate Experiment 6 in its entirety with ewes in lactation and suckling lambs. The period of lactation was so far advanced, July 7, when the experiment was begun that none of the lambs contracted milksickness, in consequence of which the detailed report of this part of the experiment is withheld. The results of feeding white snakeroot to the mothers, however, will be assembled in Table IV.

TABLE IV—DATA BEARING UPON THE FEEDING OF WHITE SNAKEROOT TO EWES IN LACTATION, IN 1917. EXPERIMENT 7.

Ewe No.	*Initial weight. Lbs.*	*Experiment begun.*	*Date of death.*	*Days before death occurred.*	*Weight at death. Lbs.*	*Gain or loss. Lbs.*	*Feed given.*			
							Grain. Lbs.	*Weed. Lbs.*	*Kale. Lbs.*	*Hay Lbs.*
31	104	July 7	Aug. 28	52	102	—2	77	26	26	52
22	81	July 7	Sept. 2*	56	83	—2	78	27	26	56
17	93	July 7	Aug. 6	30	95	2	39	14	26	30
15	93	July 7	Sept. 2	56	95	2	79	27	26	56
9	94	July 7	Aug. 22*	46	104	10	65	22	26	46
16	135	July 7	Aug. 22*	39	140	5	63	20	26	47

*Feeding was discontinued on the date indicated.

Three of the six ewes employed in this experiment died. Ewe 31 was discontinued on this experiment, however, August 20, and is subsequently reported in Experiment 11, on which she died August 28. Ewe 16 was discontinued on August 15 and is reported in Experiment 9, which resulted in her death August 22. Ewe 17 alone, which died August 6, ate most of the weed given and developed a typical case of trembles, whereas the weed given to the others was for the most part refused. Ewes Nos. 22, 15, and 9 were placed on pasture at the time of discontinuance of the experiment.

Experiment 8.—This experiment was begun on the same date as Experiment 7, in order to determine whether animals not in lactation be-

come affected with trembles earlier than those in lactation. Here again, six animals whose lambs had been weaned were selected. The data bearing on this experiment are presented in the following tabulation:

TABLE V—RESULTS OF FEEDING WHITE SNAKEROOT TO EWES WITH WEANED LAMBS. EXPERIMENT 8.

					Feed given.			
Ewe No.	*Initial weight. Lbs.*	*Experiment begun.*	*Date of death.*	*Days before death occurred.*	*Grain. Lbs.*	*Weed. Lbs.*	*Kale. Lbs.*	*Hay. Lbs.*
25	104	July 7	Sept. 2	56	79	27	24	55
158	108	July 7	Sept. 2*	56	81	27	24	55
149	98	July 7	Sept. 2*	56	81	21	24	55
163	102	July 7	Sept. 2*	56	73	27	24	55
173	105	July 7	Aug. 24	48	68	23	24	47
172	85	July 7	Sept. 7*	56	81	28	24	55

*The feeding of white snakeroot was discontinued at this date.

It may be noted above that ewe 173 died after having been on the experiment 48 days, and ewe 25 after 56 days. Both had typical cases of trembles, whereas the others remained apparently healthy when the feeding with white snakeroot was discontinued, September 2. Since the period of lactation of the ewes in Experiment 7 was so far advanced and since so few deaths occurred in both experiments 7 and 8, no conclusion can be drawn as to the influence of lactation upon the period of resistance.

Experiment 9.—Four lambs and one sheep were used in this experiment to test the toxicity of expressed sap. Lamb 237 was given 500 c.c. in the afternoon of July 30. On the morning of the following day it was given 500 c.c. and an equal quantity in the afternoon. This animal had been given 1500 c.c. and was found dead on the morning of August 1.

Lamb 241 was given 250 c.c. on July 30 and two quantities of 250 c.c. on July 31. She refused to eat oats on the morning of August 1, and was given no more plant juice until the evening of August 3, when she again appeared normal. At this time, she was given 250 c.c. On each of the two succeeding days she was given 500 c.c., making a total of 2,000 c.c. She refused to eat on the morning of August 6 and trembled when made to rise. Feeding with juice was therefore discontinued, and she died on August 9.

Lamb 231 was given daily three feedings of juice of 250 c.c. each beginning on the evening of August 6. Only 250 c.c. were given on August 10 and 500 c.c. on August 11. This lamb had received 4500 c.c. by the evening of August 13, when symptoms of trembles were manifest. Trembling was violent on the following morning and the animal died during the afternoon.

Two feedings of juice of 250 c.c. each were given daily to lamb 240. This test was begun on the evening of August 6 and was discontinued on the evening of August 13. On August 10 only half the quantity was given so that the lamb had consumed 3,000 c.c. by August 13. The animal trembled on the morning of August 14 and the tremors had become so intense by evening that it could not stand. Death occurred during the night of August 14.

Between the evening of August 16 and the evening of August 22, ewe 16 was given a total of 7,250 c.c. of expressed juice. She was sick on the evening of August 22, as noted by the characteristic standing posture. On the following morning, she stood with head lowered and with mouth held open and panted for breath. She seemed to be suffering severe abdominal pain as evidenced by efforts to vomit and constant movement of the hind limbs. Death resulted at about 4 P. M. on August 22.

Experiment 10.—This experiment with lambs 233 and 222 corresponds to Experiment 21 with guinea pigs. Expressed juice was kept on a water bath maintained at a temperature of about 60 degrees C. The decrease in volume due to evaporation was restored by the addition of water. Lamb 333 was given 500 c.c. daily in two feedings beginning on the evening of August 6. None was given on August 11. She was first noticed to tremble on August 17 and feeding was discontinued. This animal was given a total of 5,000 c.c. Death took place August 18. The feeding of lamb 222 was begun at the same time, she being given 750 c.c. daily except on August 11, when none was given. Trembling was first noted on the morning of August 25 and she died during the night of August 29. No juice was given after August 24, and she received a total of 9,250 c.c.

Experiment 11.—The residue from which the volatile oil had been distilled was given to ewe 31 beginning August 20. By the evening of August 22, 3,800 c.c. had been given. None was given on the two succeeding days, and at noon on the 25th trembling was noted. Death occurred during the night of August 27.

b. With Hogs

Experiment 12.—The purpose of this experiment was to determine whether hogs are subject to ill effects following the feeding of white snakeroot. Accordingly, two animals were given this weed along with a ration of grain and shorts beginning June 21. They consistently refused to eat any considerable quantity of the weed even though it was mixed with moistened grain and shorts. One animal, however,

contracted trembles on September 24 and died six days later. This animal is shown in figures I, J, K, and L in the accompanying illustrations. The other animal remained unaffected.

c. With Guinea Pigs

Experiment 13.—On June 26, three guinea pigs were placed on an experiment which was designed to show whether guinea pigs are subject to poisoning by the ingestion of green leaves of white snakeroot. No. 1 aborted on July 1, refused all feed on that day and on the following day, and was found dead on the morning of July 3. The autopsy showed that death very probably resulted from abortion. No. 2 also aborted on July 1, but her appetite remained quite normal until her death which occurred on July 4. She was very inactive, however, during this period, but exhibited no other indication of being affected. Abortion resulted on June 29 in the case of No. 3. She ate sparingly during succeeding days and remained humped up with eyes partially closed. Upon being disturbed, she appeared quite active. On July 6 a period of coma began and death resulted on July 9. Two more animals, No. 4 and No. 5, were placed in this cage on July 3. On July 9 No. 4 was very sick and breathed with difficulty. She became comatose and was found dead on the morning of July 11. No. 5 appeared normal until July 10 and was very inactive thereafter until her death on July 23.

Experiment 14.—Beginning June 26, two male guinea pigs were fed on green stems of white snakeroot to determine if stems are as poisonous as leaves. No. 1 was noted to be droopy on the morning of July 3 and was dead forty-eight hours later. No. 2 was first noted to be affected on July 7. He then appeared listless, refused entirely the green stems and ate only sparingly of the grain. By July 9 respirations were labored, and he sat crouched in the corner of his cage. His eyes were half-closed, his ears drooped, and his head drooped. By July 11 his body was limp and he had so lost control of his legs that when lain on his side, he could not regain his feet. At this stage, trembling was apparent. The symptoms exhibited in No. 2, which animal is shown in Fig. H, are typical of trembles in guinea pigs as developed throughout these experiments. This animal was asphyxiated on July 11 and an autopsy immediately made.

Experiment 15.—At the same time that the above experiments were begun to determine whether the leaves and stems are toxic to guinea pigs, the feeding of two animals on an aqueous extract was also begun. On June 28, some diarrheal symptoms were present, which persisted

until July 5. They ate ravenously, however, and by July 8 had eaten the water soluble material from 1800 grams of dry white snakeroot with no ill effect except the disgestive disturbance mentioned. For the next fourteen days they were given an aqueous extract prepared from the fresh weed. At the end of this time, they were in good condition and the feeding was discontinued. It does not appear from this that the active principle is water soluble, or if it is, the heat of desiccation destroys its toxicity. It will be recalled in this connection, that the feeding of aqueous extracts previously reported by Crawford (1908) were not followed by trembles.

Experiment 16.—The feeding of three guinea pigs with material extracted with dilute hydrochloric acid was begun on June 28. This extract was made neutral with sodium hydroxid with the consequent precipitation of salt. No. 1 was sick on July 2, was very inactive on July 3, but ate of the grain and clover. He refused to eat on the morning of the following day, and died at noon. The other two were still unaffected on July 8 when feeding was discontinued.

Experiment 17.—The feeding of alcohol soluble products was begun on the evening of July 3. By the evening of July 5, two guinea pigs had eaten the extract from 1,800 grams of dry weed. No ill effects whatsoever followed during the succeeding two weeks in which they were kept under observation.

Experiment 18.—In this experiment six guinea pigs were given by means of a pipette the expressed sap or juice of white snakeroot. On the evening of July 20, two large animals, each weighing nearly 800 grams, were given 10 to 12 c.c. apiece. On the following morning both were noted to be droopy and refused to eat. No. 1 was so weak that he could scarcely walk and seemed unable to control the movements in the hind limbs. Each was given about 12 c.c. on the morning of the 21st and an equal quantity at noon. At 5 P. M. No. 1 died, having been given a total of about 35 c.c. No. 2 was given two feedings on the 22d and had received a total of about 50 c.c. during the three days of feeding. He became more inactive and listless daily, passed into a state of coma and died July 26.

On the morning of the 24th two more guinea pigs were placed in this cage and each was given in three feedings about 25 c.c. Both were sick on the following morning, but were given during the day three quantities of expressed juice totaling about 25 c.c. for each animal. On the following morning No. 3 died. No 4 was fed three times daily on the 26th, 27th, and 28th. Feeding was discontinued on this last date and he died three days later.

On the afternoon of the 26th another animal, No. 6, was placed in this cage, was given 16 to 20 c.c. daily in two feeds and died on August 14. No. 6 remained quite normal throughout this entire period except for two or three days prior to death.

Experiment 19.—In this experiment the expressed sap was reduced to dryness over a water bath, the water in which was kept boiling. On July 11 one animal was placed on this experiment, and given daily the equivalent of 25 to 30 c.c. of freshly expressed juice. No ill effects had appeared on July 20, when feeding was discontinued.

This animal along with two others was again placed on the experiment on July 26. Each was given daily quantities equivalent to 25 or 30 c.c. of fresh sap. Since no ill effects had appeared by August 14, the feeding was discontinued. When it is remembered that the sap was toxic before it was desiccated and that each animal had received the equivalent of many times more of fresh juice than was necessary to produce death, it is evident that desiccation at high temperature either destroys the toxicity or that the active principle had been volatilized.

Experiment 20.—This experiment was designed to show whether a toxic volatile principle is present in the sap of white snakeroot. Accordingly, 5,800 c.c. of expressed sap were distilled in a flask over an open flame. A turbid distillate was collected which contained a very pungent volatile oil. This distillate was fed to three guinea pigs beginning August 14 and concluding August 29. No ill effects whatsoever were apparent. The materials which remained after distillation were fed to ewe 31 and have been reported as Experiment 11 along with the feeding experiments with these animals.

Experiment 21.—The expressed sap fed to the three animals on this experiment had been kept for forty-eight hours on a water bath maintained at 55 to 60 degrees C. This temperature was found to be sufficient to drive off the volatile oil and was believed to be hot enough to prevent fermentation yet not a sufficient degree of heat to change the chemical constitution of the plant juice. The feeding of two animals, thrice daily, was commenced at noon on July 30 and of another on August 3. One of the first two was observed to be sick on August 2. This animal died on the afternoon of August 4. The other two continued to eat their food, however, and were merely less active than normal individuals throughout the remainder of the time that they were maintained on this product or until August 23.

TRANSMISSION OF THE DISEASE.

a. By Milk and Milk Products

In sections where milksickness prevails, it is firmly believed the disease is acquired through the use of milk from cattle affected with trembles. There seems, moreover, to have been little doubt of this fact in the minds of early settlers in the Middle West and more or less evidence has been presented in published accounts by McCall (1822), Lewis (1829), Barbee (1840), Logan (1849), Yandell (1852), Philips (1857), Cosby (1866), Nichols (1876), Woodfin (1878), Sykes (1891), Beck (1905), and McCoy (1907), in the several medical journals.

An instance of an apparent exception came under the observation of Jordan and Harris (1909) during the summer of 1908. Four cases of milksickness in a family of ten developed near Altamonte, Ill., on a farm which had "long been known to give rise to milksickness." In discussing the occurrence, they state that "The cows were to all appearance entirely healthy, and showed no signs of disease before or after the outbreak; a six-to-eight weeks old calf whose mother was one of the animals providing the milk used in the family also seemed in the best of condition. A cat that was being fed on the milk from these cows was itself well, but lost all of its eight-weeks-old kittens, five in number, during the outbreak in the family. A dog receiving milk from the same cattle showed signs of illness and was noticed to vomit repeatedly."

This case does not entirely agree with the claim quite commonly advanced in "milksick" sections in the State to the effect that so long as cows are being milked or their calves are suckling, they show no signs of trembles. The calves, however, may sicken and die or persons who use the milk may be affected with milksickness. In due time, however, the milk is suspected and in consequence, the cows are left to go dry and then develop the disease. This peculiarity furthermore finds support in the writings of Drake (1841), Graff (1841), and Kimmel (1891). It is further strengthened by the common observation among farmers that in the herd of cows, heifers, and steers, the heifers and steers become affected earlier than cows in lactation.

To Lambs.—Experiment 22.—The present experiments bearing upon the acquisition of milksickness through the milk deal with suckling lambs whose mothers were fed white snakeroot as previously recorded in Table III. The mothers of the lambs, the data on which lambs are recorded in Table VI, were also well advanced in the period of lactation as were those reported in Table IV. This fact is believed to be the potent factor in determining the small number of cases of milksickness which developed.

TABLE VI—RESULTS OF TRANSMISSION OF THE DISEASE THROUGH THE MILK FROM EWES TO LAMBS. EXPERIMENT 22.

Animal No.								*Feed given.*	
Ewe No.	*Lamb No.*	*Initial weight. Lbs.*	*Experiment begun*	*Date of death.*	*No. days on experiment.*	*Weight at death. Lbs.*	*Gain or loss. Lbs.*	*Grain. Lbs.*	*Kale. Lbs.*
171	244	38	May 13	June 17	35	27.5	—10.5	9	33
162	243	50	May 13	July 25*	73	61	11	30	71
175	242	40	May 13	June 17	35	39	—1	15	32
167	241	33	May 13	July 25*	73	32	—15	36	71
12	237	46	May 13	July 25*	73	56	10	35	71
168	200	48	May 13	July 15*	83	45	—3	35	60

*These lambs were put on pasture on the dates indicated.

Two lambs, Nos. 244 and 242, developed genuine cases of milksickness and died thirty-five days after the experiment was begun, June 17. Ewe 171, the mother of lamb 244, showed no evidence of trembles until a few days before her death, which occurred, as noted before, on August 30. These individuals are shown in Fig. G, at a time when the lamb had passed into a state of coma. The mother of lamb 244 never manifested any evidence of trembles although she was continued on the experiment until September 2. This fact accords with the observation which has previously been made by Jordan and Harris (1909) that animals can transmit the disease through the milk without themselves ever manifesting any signs of the disorder.

Lambs 237 and 241 were employed after this experiment was concluded in tests on the toxicity of expressed sap as has been reported in Experiment 21. The other two lambs, Nos. 243 and 200, were placed on pasture.

The butter from cows affected with trembles is also generally believed to be the source of milksickness. A number of publications dealing with this phase of the subject have appeared in which the authors, among whom are Johnson (1866), Gray (1881), Beach (1883), Scott (1889), Beck (1905), and Jordan and Harris (1909), commit themselves to this belief. The last named writers describe an outbreak which came under their observation at Morris, Ill., in 1908. Five cases developed in a family which secured butter from a farm six miles distant. The cows which gave the milk from which this butter was made, ranged in woodland in which eight cattle had contracted trembles two years earlier. About a month after the recovery of these five persons, a typical case appeared in one of the young men on the farm from which the butter had been procured. In concluding this account, they state that "There seems little doubt, therefore, in view of all the facts, that butter brought from the 'milksick' farm was responsible for the cases."

To Mice.—Experiment 23.—Opportunity has not been afforded in the present experimental study to secure conclusive data upon butter as an agency in the transmission of milksickness. Three mice were fed butter made from the milk of a cow feeding upon white snakeroot. One died about two weeks after feeding was begun, another a week later, while the other one remained unaffected. Aside from general debility, no other symptom was prominent in these two animals, and the cause of their death could not be determined with certainty. It is reasonable to conclude, however, in the light of experiments on milk as a carrier of milksickness, that the disease may be transmitted through butter.

No clear-cut evidence pointing to a relationship between cheese and the development of the disease appears in available medical literature. Some few writers (Scott, 1889) assume that it is a generally accepted fact and in view of the evidence that milk and butter are capable of transmitting the disease, it is logical to suppose that cheese may also be a carrier. No feeding tests, however, have ever been directed toward the settlement of this claim.

b. Through the Agency of Meat

Numerous records exist of the transmission of this disease through the eating of flesh of animals affected with trembles. Coleman (1822), Lewis (1829), Sale (1891), and Conner (1904) cite specific instances of the acquisition, by man, of this disease from meat. Yandell (1867) has included in his account statements which are contrary to this idea. Statements apparently from eye-witnesses (Coleman, 1822; De Bruler, 1858) have, moreover, been made to the effect that carnivorous animals may acquire the disease from the flesh of animals dead of trembles. More remarkable than this, however, is the statement that these animals can transmit the disease to others indefinitely. Instances like the following from McCall's (1830) report illustrate the point in question. Some sheep which died of trembles were eaten by hogs, which in turn, succumbed to the same disease. The carcasses of all of the hogs except one were burned. Chickens which ate of this one were eaten in turn by persons who subsequently developed cases of milksickness. Another similar record by De Bruler (1858) states that a cow gave the disease to her calf, whose body was eaten by dogs. The dogs in turn died of trembles and a pet crow which fed on the dogs' flesh also died.

The more recent experiments by Jordan and Harris (1909) in which four dogs were fed upon flesh of animals dead of trembles resulted in the production of no ill effects.

To Dogs.—Experiment 24.—These results with meat are in accord with the results secured in the present studies. During 1916, the car-

casses, including livers, hearts, kidneys, and spleens of three sheep dead of trembles were fed to three dogs with no resultant ill effects. During the next season, four dogs were given the bodies of eight animals with no manifestation of trembles. It can only be suggested with reference to the observations of others to the effect that carnivorous animals may die after having eaten the flesh of an animal dead of trembles, that ptomaines may have been present as the result of bacterial growth. This was guarded against in the present experiments by placing the carcasses, immediately after the autopsies had been performed, in a refrigerator. Daily portions were then given sufficient to satisfy the dogs' hunger.

Summary of Feeding Experiments.

During the course of the feeding experiments with white snakeroot, a total of 41 sheep and lambs have been subjected to experimental conditions. Three others died in the experimental work with sodium compounds, to be reported later in this paper. Twenty-eight of these died and all except two were observed to have been characteristically affected with trembles or milksickness. These two were infested with stomach worms, which infestation may have been a contributory cause of their death. Two lambs contracted milksickness from the milk of ewes feeding upon white snakeroot.

Two hogs were fed white snakeroot. One of these animals contracted a fatal case of trembles and the other remained apparently unaffected.

Twenty-nine guinea pigs, fifteen of which succumbed on the experiments, were given white snakeroot or some of the products prepared from this plant.

Seven dogs ate of the flesh of sheep dead of trembles with manifestly no ill effects.

Three mice were given butter from the milk of a cow feeding upon white snakeroot. Two of them died while the other remained unaffected.

Post-Mortem Examinations

No detailed studies of the pathological anatomy of animals dead of trembles or milksickness, other than those of Jordan and Harris (1909) appear in the voluminous literature on this disease. These authors give a general historical account of autopsies by other writers. These accounts give the impression of being fragmentary and indicate a lack of familiarity with anatomy in general and of experience with making post-mortem examinations. Such statements as the following indicate the point in question.

Bennett (1822) says that the stomach contents of cattle is dry and that the liver has a morbid appearance. Beck (1822) describes the heart and aorta as greatly enlarged and their inner coat sloughy. Mil-

ler (1867) asserts that gastric and hepatic lesions accompany the disease. Hibberd (1844) mentions the finding of a diminution of the caliber of the stomach and intestine in all of the cases examined. Mendenhall (1861) describes the inner coat of the stomach and intestine as being gangrenous. Newman (1867) records the singular observation that "in examining a milk cow after death the skin was found very much thickened and covered with small pustules." Dicky (1852) states that the peritoneum and small intestine showed signs of inflammation. Graff (1841) says that there is evidence of cerebral inflammation, of a similar condition of the stomach and small intestines, that the spleen is enlarged and the liver softened. Way (1893) noted congestion of the cerebral meninges in the case of a six-weeks-old calf.

Jordan and Harris (1909) had opportunity to perform autopsies upon several cattle, two lambs, and one horse. The following account of the microscopical appearance of these animals covers their findings. Externally the body presents nothing on inspection that is worthy of note. There may be present in the pleural cavities a small quantity of clear, yellow fluid. On opening the thoracic cavity, the lungs do not collapse. A quantity of frothy fluid exudes from the sectioned surface of the lungs. As a rule, the pericardial sac contains varying quantities of clear, straw-colored fluid which coagulates when exposed to the air. Numerous ecchymotic areas which are more numerous at the base of the heart, occur along the course of the cardiac veins. There was noted on section of the heart either fatty areas or streaks, or cloudy swelling.

The peritoneal cavity contains no abnormal amount of serous fluid. The liver is uniformly enlarged and of a purple color, being full of blood. The consistency of the liver substance is soft and friable, and of the "nutmeg" appearance. Blood drips freely from the sectioned surface. The parenchymatous tissue is fatty. The kidneys are always enlarged and engorged with blood. Cloudy swelling of the parenchyma and in some cases slight fatty changes are noted. The bladder may be injected. In some cases, the urine is cloudy and apparently contains blood. The mucosa of the small intestines may show injection and ecchymoses. The meningeal vessels of the brain appear congested.

In the microscopical examination, these authors find that the most profound pathological changes occur in the heart, liver, and kidneys. In the heart there may be noted cloudy swelling and fatty changes. In the liver the parenchymatous cells appear swollen with more or less cloudy swelling and fatty metamorphoses. The central veins are distended with blood. The kidneys show hyperemia, glomerulitis, and parenchymatous degeneration.

The following is a detailed report of seven representative cases in sheep and lambs.

CLINICAL DATA ON CASE 1, TABLE VII, SHOWING TEMPERATURE, PULSE, AND RESPIRATION OF EWE 168.

	Temperature.			Pulse.			Respiration.			Atmospheric Temperature.			Character of Day
Date.	A. M.	M.	P. M.	A. M.	M.	P. M.	A. M.	M.	P. M.	Max.	Min.	Mean	
5–11	.....	.....	103.6	.....	.....	63	.....	.....	30	70	47	58	Cloudy.
5–12	.....	.....	103.8	.....	.....	60	.....	.....	42	61	46	54	Partly cloudy.
5–13	.....	102.1	.....	.....	60	.....	.....	48	.....	60	42	51	Partly cloudy.
5–14	102.1	101.2	102.0	66	69	54	48	43	30	66	43	54	Partly cloudy.
5–15	101.4	101.3	103.5	60	54	66	42	36	48	76	49	62	Clear.
5–16	102.0	102.0	101.9	60	66	66	45	42	48	80	57	68	Cloudy.
5–17	101.7	101.9	102.1	60	63	66	30	45	48	85	62	74	Clear.
5–18	101.4	102.0	102.2	63	60	60	36	39	45	87	65	76	Clear.
5–19	101.8	101.6	102.6	69	66	66	42	48	54	92	64	78	Clear.
5–20	101.6	102.1	102.6	54	60	66	36	54	57	90	65	78	Clear.
5–21	101.6	102.0	102.7	72	75	72	33	42	60	90	64	77	Clear.
5–22	102.1	102.2	102.7	66	54	60	42	42	66	88	62	75	Clear.
5–23	101.5	102.8	102.8	54	66	60	30	42	42	76	55	66	Partly cloudy.
5–24	100.6	101.6	102.6	60	63	60	27	33	33	72	49	60	Clear.
5–25	101.4	101.0	102.2	66	69	69	27	33	36	77	55	66	Partly cloudy.
5–26	101.2	102.0	102.6	57	60	72	30	30	36	77	53	65	Partly cloudy.
5–27	101.7	102.0	102.6	66	72	63	27	42	36	86	64	75	Cloudy.
5–28	101.7	101.3	102.6	66	57	60	30	30	42	80	68	74	Cloudy.
5–29	101.4	.....	101.8	66	.....	60	48	.....	36	78	59	68	Clear.
5–30	101.3	101.6	101.5	60	60	66	30	36	42	82	55	68	Clear.
5–31	101.8	102.4	101.5	66	66	60	36	36	30	78	59	68	Cloudy.
6– 1	101.3	103.0	102.8	66	66	63	36	42	54	89	66	78	Partly cloudy.
6– 2	102.0	102.4	103.3	75	66	69	42	48	54	90	65	78	Clear.
6– 3	102.2	102.6	103.4	69	57	66	48	72	60	91	66	78	Partly cloudy.
6– 4	101.8	102.4	102.6	66	69	72	36	36	42	73	64	68	Cloudy.
6– 5	101.9	101.9	102.4	66	69	78	36	33	42	85	64	74	Partly cloudy.
6– 6	102.2	102.0	103.0	72	72	66	36	42	54	89	67	78	Partly cloudy.
6– 7	101.8	102.3	103.0	60	66	63	30	45	54	84	70	77	Partly cloudy.
6– 8	102.0	102.8	102.6	66	66	63	36	39	36	86	64	75	Partly cloudy.
6– 9	101.6	102.0	102.2	72	63	59	42	66	54	86	64	75	Partly cloudy.
6–10	101.6	101.4	101.5	66	66	63	30	30	27	76	64	70	Cloudy.
6–11	101.2	101.5	102.2	63	66	66	33	33	30	83	65	74	Partly cloudy.
6–12	101.4	102.2	102.8	75	60	57	36	30	54	88	67	78	Clear.
6–13	101.6	101.4	102.2	78	57	60	39	30	48	88	68	78	Partly cloudy.
6–14	101.5	101.8	102.0	63	60	66	27	36	27	84	68	74	Cloudy.
6–15	100.7	102.2	102.4	68	60	57	33	30	27	78	62	70	Partly cloudy.
6–16	101.6	101.2	101.6	60	57	57	30	36	27	73	56	64	Clear.
6–17	99.6	100.3	101.8	60	63	63	42	36	36	76	54	65	Clear.
6–18	100.5	101.2	102.0	66	72	57	42	30	39	82	58	70	Clear.
6–19	100.8	101.2	101.8	51	54	60	36	30	45	80	60	70	Cloudy.
6–20	101.8	102.0	102.4	60	60	63	36	39	66	85	63	74	Clear.
6–21	101.4	102.2	102.4	60	66	60	48	42	66	88	64	76	Partly cloudy.
6–22	100.8	101.0	101.6	66	66	63	30	48	54	85	63	74	Clear.
6–23	101.8	102.2	102.4	54	60	63	24	54	60	91	69	80	Clear.
6–24	102.0	103.0	103.5	66	72	60	48	84	72	93	67	80	Clear.
6–25	102.1	102.6	103.3	66	75	60	48	81	84	88	68	78	Clear.
6–26	101.6	102.0	103.5	72	72	66	57	72	90	91	72	82	Partly cloudy.
6–27	102.6	102.2	103.4	72	69	66	60	84	96	92	71	82	Clear.
6–28	102.0	102.4	102.6	75	66	69	54	72	84	90	69	80	Partly cloudy.
6–29	101.6	101.8	102.4	72	66	69	48	60	48	86	67	76	Cloudy.
6–30	102.2	101.8	102.6	66	63	63	36	54	54	84	65	74	Partly cloudy.
7– 1	101.8	102.2	102.5	60	60	57	48	48	63	87	67	77	Clear.
7– 2	102.0	102.2	102.9	60	66	63	33	54	54	88	67	78	Partly cloudy.
7– 3	102.2	101.8	102.3	60	63	60	36	45	66	85	67	76	Cloudy.
7– 4	102.2	102.0	102.1	60	60	63	39	54	36	79	65	72	Cloudy.
7– 5	101.9	102.2	103.0	60	66	69	51	66	66	85	63	74	Partly cloudy.
7– 6	102.0	102.3	102.0	60	66	63	48	57	48	83	69	76	Partly cloudy.
7– 7	102.0	102.6	102.8	63	66	66	42	42	36	81	69	75	Cloudy.
7– 8	102.0	101.8	101.8	54	66	60	36	60	48	86	68	78	Partly cloudy.
7– 9	102.3	101.9	102.6	72	63	66	42	48	72	89	70	70	Clear.
7–10	102.2	102.6	103.0	66	63	60	48	48	54	88	67	78	Partly cloudy.
7–11	102.2	103.2	102.7	51	54	60	36	48	42	83	66	74	Clear.
7–12	102.4	102.5	102.4	57	60	66	42	54	54	92	67	80	Partly cloudy.
7–13	101.6	101.6	102.2	63	66	72	30	36	57	86	67	76	Partly cloudy.
7–14	101.4	101.5	102.4	75	72	78	42	48	48	86	67	76	Partly cloudy.
7–15	104.2	Died	.....	69	.....	.....	42	.....	.....	90	69	80	Clear.
7–16	.....	.....	.....	.....	.....	.....	.....	.....	.....	91	69	80	Clear.
7–17	.....	.....	.....	.....	.....	.....	.....	.....	.....	90	67	78	Partly cloudy.
7–18	.....	.....	.....	.....	.....	.....	.....	.....	.....	82	66	74	Cloudy.
7–19	.....	.....	.....	.....	.....	.....	.....	.....	.....	78	66	72	Cloudy.
7–20	.....	.....	.....	.....	.....	.....	.....	.....	.....	79	68	74	Cloudy.
7–21	.....	.....	.....	.....	.....	.....	.....	.....	.....	80	69	74	Cloudy.
7–22	.....	.....	.....	.....	.....	.....	.....	.....	.....	86	71	78	Partly cloudy.
7–23	.....	.....	.....	.....	.....	.....	.....	.....	.....	89	72	80	Partly cloudy.

These data show that in ewe 168 there were no marked abnormalities in temperature, pulse, and respiration. There has been included with this table a statement of the meteoric conditions since they exert an influence upon the temperature, pulse, and respiration of animals.

Clinical Notes. The first symptoms appeared July 13, when the respiration was slightly jerky. On the 14th, she lay with head and neck extended and jaw resting upon the ground. After standing for about a half-minute, she would begin to tremble as noted in all the other cases. As soon as trembling began, she would lie down. In the afternoon the symptoms were more aggravated. She went into a state of coma during the night before she died, and death occurred July 15, at about 8 A. M.

Blood Study. On May 18 a study was made of the blood of ewe 168 to determine the normal condition prior to the feeding of white snakeroot. The following is the result of this study:

Numerical count:	
Erythrocytes	8,040,000
Leucocytes	14,000
Differential count:	
Neutrophiles	46 per cent
Lymphocytes, large	4 per cent
Lymphocytes, small	45 per cent
Eosinophiles	2 per cent
Mast cells	3 per cent
Hemaglobin	72 per cent

On July 14 a study of the blood was made with the following result:

Numerical court:	
Erythrocytes	9,540,000
Leucocytes	9,000
Differential count:	
Neutrophiles	45 per cent
Lymphocytes, large	14 per cent
Lymphocytes, small	39 per cent
Mast cells	2 per cent
Hemaglobin	72 per cent

There was thus a slight increase in the small lymphocytes at the expense of the large lymphocytes, a slight increase in the erythrocytes, and a numerical decrease in the leucocytes. The hemaglobin remained normal.

Protocol. Externally the body presents nothing worthy of note.

The Thoracic Cavity.—The lungs appear normal and collapse when the thorax is opened. There is neither pneumonia, broncho-pneumonia, nor pleuritis. The color of the lung is pale salmon. No excess of fluid is found in the thoracic cavity.

The Heart.—There is an excessive amount of pericardial fluid. Petechiation of the epicardium in the region of the coronary arteries and at the base of the heart is noted. The heart is filled with dark, coagulated blood. There are no agony thrombi and the muscles appear pale in color.

The Abdominal Cavity.—An excessive amount of serous fluid exists in the abdominal cavity. Muco-enteritis involving the abomasum and duodenum and a portion of the jejunum is present. Stomach worms are found in the abomasum. The small and large intestines are affected with nodular disease. The large intestines otherwise appear normal.

The Liver.—The liver weighs one pound thirteen and one-half ounces. It is of a dark metallic color and is congested so that blood drips from the sectioned surface. The gall bladder is filled with a rather dark, tarry bile. Cloudy swelling is evidently present.

The Kidneys.—Both kidneys weigh four and one-half ounces. Externally they present a metallic color. Both active and passive congestion and cloudy swelling are present. The glomerules can be noted as minute, red pin point-like spots in the renal cortex.

The Bladder.—Empty and apparently normal.

The Musculature.—Normal.

The Brain.—Congested.

The Lympth Glands.—Normal.

Microscopical Examination. *The Liver.*—Both active and passive congestion, cloudy swelling and fatty degeneration are noted.

The Kidneys.—Both active and passive congestion are present. Glomerulitis is noted and some of the convoluted tubules show evidence of fatty degeneration.

The Brain.—The blood vessels are congested. An occasional polymorphonuclear leucocyte and plasma cells occur throughout the tissues. The brain cells are not shrunken and appear normal.

The heart.—The heart muscle fibers have lost their cross striation and many areas show fatty degeneration. The nuclei stain deeply, in fact, may be considered picnotic. The blood vessels are congested:

The Lungs.—Normal.

The Lymph Glands.—Normal.

The Pancreas.—Normal.

The Adrenal Glands.—Normal.

The Duodenum.—The duodenum is infiltrated with round cells.

The Blood Vessels.—Congested.

CASE 2, TABLE VIII, SHOWING TEMPERATURE, PULSE, AND RESPIRATION OF LAMB 200.

	Temperature.			*Pulse.*			*Respiration.*		
Date.	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*
5–11	.....	.....	103.1	80	....	80	.....	.....	112
5–12	.....	.....	104.0	....	....	72	.....	.....	96
5–13	.....	103.2	.....	....	72	....	79	.....	.....
5–14	103.2	.....	102.8	78	86	72	72	87	54
5–15	102.9	102.9	103.1	78	90	84	66	108	90
5–16	103.3	102.9	103.3	84	84	79	90	120	114
5–17	103.7	103.6	103.4	78	84	78	126	120	132
5–18	103.6	103.2	103.0	84	96	88	132	126	132
5–19	104.0	104.0	103.4	78	78	78	126	142	132
5–20	103.6	103.7	103.9	84	84	78	139	156	156
5–21	103.8	103.0	103.9	78	84	87	138	144	158
5–22	104.0	103.4	103.4	84	78	84	114	114	132
5–23	103.6	103.8	103.7	84	84	84	138	144	147
5–24	103.2	103.2	103.2	84	84	78	78	90	102
5–25	103.0	103.0	103.4	72	78	84	90	96	108
5–26	103.2	103.0	103.1	87	84	84	90	78	138
5–27	103.8	103.6	103.4	84	72	72	108	114	102
5–28	103.2	103.6	103.8	72	66	72	72	90	108
5–29	103.0	.....	103.9	81	....	78	72	.....	90
5–30	102.7	103.0	103.7	72	84	72	60	108	78
5–31	103.0	103.1	103.7	69	72	78	66	84	90
6– 1	104.0	103.9	103.9	84	69	72	120	126	108
6– 2	103.0	103.3	103.4	78	69	72	108	126	138
6– 3	104.0	104.0	103.9	72	81	72	120	114	126
6– 4	103.0	103.7	103.8	75	84	84	84	96	120
6– 5	103.2	103.6	103.7	78	84	81	105	102	102
6– 6	103.2	103.6	103.9	75	72	87	114	102	108

	Temperature.			Pulse.			Respiration.		
Date.	A.M.	M.	P.M.	A.M.	M.	P.M.	A.M.	M.	P.M.
6– 7	103.4	103.7	104.2	72	75	81	108	108	102
6– 8	103.9	104.0	103.8	84	75	90	96	108	126
6– 9	102.8	103.0	103.2	72	84	75	84	90	78
6–10	103.3	103.8	103.7	72	84	84	54	87	90
6–11	103.4	103.8	103.8	78	87	81	96	114	114
6–12	103.4	103.8	103.8	81	78	82	114	120	132
6–13	103.8	104.2	104.2	72	72	75	96	96	120
6–14	104.3	104.1	103.8	81	75	60	114	120	102
6–15	103.1	104.0	104.7	72	66	66	66	90	96
6–16	102.8	103.3	104.0	78	72	60	90	60	60
6–17	102.4	103.5	104.2	60	60	54	72	66	60
6–18	103.3	103.0	103.0	63	60	60	84	90	102
6–19	103.2	103.5	103.8	60	57	66	54	72	78
6–20	103.1	104.1	104.2	72	60	72	90	90	96
6–21	103.4	104.2	104.2	69	75	63	102	90	96
6–22	103.4	103.4	104.1	72	69	78	78	108	78
6–23	103.9	104.5	104.0	69	72	75	60	90	108
6–24	104.0	104.1	104.0	72	78	72	90	120	114
6–25	103.7	103.4	104.0	60	72	69	90	90	108
6–26	103.5	104.0	104.2	69	66	66	96	90	120
6–27	103.6	104.0	104.4	69	72	60	120	120	102
6–28	102.9	104.0	103.9	63	61	68	60	108	114
6–29	104.2	103.6	104.0	66	72	60	90	96	78
6–30	103.1	103.5	103.5	66	72	72	54	90	96
7– 1	103.6	103.6	104.0	54	66	57	66	90	78
7– 2	103.6	104.2	104.0	60	72	60	78	96	96
7– 3	103.8	103.4	103.4	60	69	54	54	75	36
7– 4	103.2	103.4	103.9	66	60	60	66	48	72
7– 5	103.4	103.4	103.8	54	66	69	48	78	108
7– 6	103.2	103.6	103.5	66	66	72	66	84	90
7– 7	103.4	103.8	103.7	72	72	66	90	84	90
7– 8	103.2	103.9	103.8	54	57	60	48	84	108
7– 9	103.2	103.6	103.6	57	51	57	66	66	90
7–10	103.7	104.0	104.1	63	60	66	84	108	144
7–11	103.1	103.0	104.0	60	54	54	36	48	72
7–12	103.5	103.9	104.3	60	60	66	78	78	90
7–13	103.3	103.8	104.1	66	66	69	73	72	90
7–14	103.2	103.7	104.6	54	60	69	66	84	84
7–15	103.5	103.5	103.8	60	63	60	66	84	96
7–16	103.4	104.1	104.0	60	66	60	78	90	96
7–17	103.8	103.9	103.9	66	60	72	108	72	84
7–18	103.8	104.0	103.0	66	66	69	54	84	78
7–19	103.4	104.0	103.4	69	63	66	72	84	78
7–20	104.7	103.8	103.6	72	69	60	90	72	72
7–21	103.8	104.4	103.8	66	63	69	102	90	84
7–22	103.9	103.9	103.5	66	69	66	96	102	108
7–23	104.2	104.3	103.7	57	60	66	102	78	168
7–24	103.9	103.8	103.6	60	66	66	84	114	108
7–25	103.7	104.0	103.8	69	69	72	90	96	90
7–26	103.8	103.9	103.6	66	66	72	108	114	102
7–27	103.8	104.2	104.0	60	72	72	102	114	114
7–28	104.4	103.8	104.4	72	75	78	102	102	120
7–29	103.9	104.2	104.3	69	72	72	84	114	114
7–30	105.0	104.7	104.8	69	72	66	108	114	132
7–31	104.9	105.0	105.1	72	66	72	108	114	120
8– 1	104.7	104.8	105.0	69	72	69	120	126	120
8– 2	104.7	104.8	105.1	72	69	72	120	114	120
8– 3	103.8	103.9	104.4	78	84	81	66	108	108
									Died

These data show a slight disturbance in temperature and pulse and a very considerable increase in respiration.

Clinical Notes. The feed consisted of one-half pound of oats and one-fourth pound of weeds given twice daily and one pound of kale at noon. Feeding was begun July 16, and during this experiment this animal received 17 pounds of oats, 8.7 pounds of white snakeroot, and 17 pounds of kale. The first symptoms were noted August 1, when she appeared to be sluggish, with loss of appetite. On August 3 she ate sparingly. After standing about three-quarters of a minute she began to tremble and would soon lie down. Respirations were accompanied by groaning. At noon, the trembling was more violent than in the morning and she could not remain standing as long. During the afternoon she lay with neck outstretched and jaw resting upon the ground. She was found dead the next morning.

Blood Study. On May 18 a study was made of the blood to determine its normal condition. The following are the results:

Numerical count:	
Erythrocytes	13,760,000
Leucocytes	11,000
Differential count:	
Neutrophiles	19 per cent
Lymphocytes, large	5 per cent
Lymphocytes, small	72 per cent
Eosinophiles	4 per cent
Hemaglobin	77 per cent

On August 3, after severe symptoms had developed, another study was made. The results are as follows:

Numerical count:	
Erythrocytes	15,520,000
Leucocytes	7,000
Differential count:	
Neutrophiles	59 per cent
Lymphocytes, large	13 per cent
Lymphocytes, small	28 per cent
Hemaglobin	78 per cent

There was an apparent increase in the erythrocytes and an increase in neutrophiles at the expense of lymphocytes. There was a marked decrease in the total number of leucocytes. The decrease may have been in the lymphocytes, in which case there would be an apparent increase in the neutrophiles over the lymphocytes. The eosinophiles have entirely disappeared. The hemaglobin remains the same.

Urine Study. A study of the urine was made after severe symptoms of trembling had developed. The following is the result:

Physical examination:
- Color—Light port wine.
- Specific gravity—1015.

Chemical examination:
- Reaction—Neutral.
- Albumin—Present.
- Sugar—None.
- Carbonates—Present.
- Sulphates—Present.
- Phosphates—Present.
- Chlorides—Present.
- Hemaglobin—None.

Microscopic examination:
- Granular tube casts—Present.
- Epithelia—
  - Circular cells.
  - Spindle cells.
  - Squamous cells.

Albuminuria is present and the color indicates that hemaglobin may be present; however, Heller's test for the same was negative. She was normally

eliminating her chlorides, carbonates, phosphates, and sulphates. Tube casts of a granular type are present.

Protocol. There is a discharge from the nostrils indicating that vomiting might have taken place. Otherwise the body presents nothing on inspection that is to be considered worthy of note. There is no conjunctivitis. The lymph glands are not palpable, and there are no cutaneous and subcutaneous lesions.

The Thoracic Cavity.—There is evidence of neither pleuritis, pneumonia, nor bronchitis. The lungs do not collapse when the thorax is opened. The sectioned surface of the lungs shows a frothy, bloody material. The lungs are congested. No ecchymoses are found on the serous surfaces of the pleura or pericardium.

The Heart.—The pericardium appears normal, and there is no evidence of endocarditis. The left side of the heart is filled with dark, coagulated blood. There is no antemortem clot. The heart muscles appear pale.

The Abdominal Cavity.—The quantity of fluid in the abdominal cavity is normal. There is no peritonitis and both small and large intestines appear normal. The abomasum and duodenum are injected and the mucosa shows evidence of muco-enteritis. No stomach worms are present.

The Spleen is normal.

The Lymph Glands are normal.

The Musculature is normal.

The Brain appears somewhat congested.

The Bladder is filled with urine.

The Liver.—The liver appears dark and congested. When cut, the blood drips from the sectioned surface.

The Kidneys.—The capsules present a metallic appearance. The kidneys appear swollen and their capsules, which are easily separable, are tense. Both active and passive congestion are noted. The glomerules can be recognized as minute red, pin-point-like spots prominent throughout the cortical portion of the kidneys. The grayish appearance of the parenchyma gives evidence of cloudy swelling.

Cultural Examination.—Two cultures on glycerine agar and plain agar from both the liver and kidney were made with negative results.

Blood smears with Romanowsky's stain were negative. Smears made from the liver substance and stained with fuchsin were likewise negative.

Microscopical Examination. *The Liver.*—Sections of the liver show advanced fatty degenerative changes. They also present the appearance of both active and passive congestion and cloudy swelling.

The Kidneys—Both active and passive congestion and glomerulitis are present. The glomerules are congested and shrunken, leaving a space between the glomerule and the capsule of Bowman (Fig. N). Cloudy swelling is present (Fig. M). In some areas the lumina of the convoluted tubules are obliterated, the cells being swollen and pushed out toward the center. Cytoplasm is granular and many of the cells have lost their nuclei.

The Lungs.—The lungs are congested and there is an occasional air cell in which are noted a few erythrocytes and polymorphonuclear leucocytes.

The Brain.—The vessels of the brain are congested. An occasional plasma cell occurs throughout the tissues. Some areas show cellular invasion, the

kind of cell being mostly of the small round type. The brain cells appear normal.

The Pancreas is normal.

The Adrenal Glands are normal.

The Heart muscle shows some fatty degeneration and in these areas the muscle fibers have lost their cross-striation.

CASE 3, TABLE IX, SHOWING TEMPERATURE, PULSE, AND RESPIRATION OF LAMB 241.

	Temperature.			*Pulse.*			*Respiration.*		
Date.	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*
5–11	.....	.....	104.1	....	....	82	.....	.....	74
5–12	.....	.....	104.0	....	....	66	.....	.....	70
5–13	.....	104.0	.....	....	63	....	.....	71	.....
5–14	103.1	103.0	103.2	80	84	72	78	80	48
5–15	102.9	103.1	103.0	78	120	84	57	108	114
5–16	102.5	102.6	103.2	72	72	84	84	96	108
5–17	103.7	103.9	103.0	96	88	88	168	172	150
5–18	103.7	102.2	102.5	90	84	84	150	114	118
5–19	103.6	103.2	103.6	72	70	78	156	168	190
5–20	103.5	103.0	102.7	84	84	80	180	190	186
5–21	103.1	102.5	103.8	96	90	84	186	162	168
5–22	103.4	103.7	103.6	84	78	78	178	156	178
5–23	103.9	103.7	103.3	84	90	84	129	126	156
5–24	102.8	103.2	103.2	84	78	84	120	120	108
5–25	103.0	103.0	102.4	84	78	72	126	96	144
5–26	103.4	103.8	103.7	90	87	84	102	132	120
5–27	103.3	103.2	103.7	75	84	72	96	150	156
5–28	103.8	103.3	103.5	72	84	84	144	138	132
5–29	102.8	.....	102.6	84	....	84	54	.....	84
5–30	102.8	103.0	103.0	72	78	84	102	114	114
5–31	103.0	103.2	103.0	84	87	75	88	62	108
6– 1	103.0	103.2	103.0	78	78	78	132	144	126
6– 2	103.1	103.4	103.0	75	81	90	138	108	132
6– 3	103.2	103.5	103.5	78	75	72	156	138	78
6– 4	103.1	104.0	103.5	75	84	87	90	86	102
6– 5	103.0	103.0	103.3	75	84	72	66	96	72
6– 6	103.4	103.6	104.0	87	75	75	126	102	108
6– 7	103.7	103.6	104.1	75	78	69	48	102	90
6– 8	104.1	104.2	103.7	78	75	78	90	102	60
6– 9	103.2	103.8	103.6	72	72	75	54	48	84
6–10	103.2	103.2	103.5	81	78	84	60	84	78
6–11	102.8	103.6	104.2	72	78	75	54	96	120*
6–12	104.9	105.2	105.4	84	84	90	102	132	154
6–13	105.6	103.7	105.7	72	84	90	120	120	126
6–14	106.2	106.2	106.0	75	78	87	144	120	66
6–15	106.3	105.4	105.7	78	72	78	60	78	66
6–16	105.9	105.9	105.6	72	81	78	54	54	60
6–17	106.0	105.4	105.4	84	78	75	96	108	78
6–18	105.9	105.1	105.4	72	90	72	66	132	96
6–19	104.8	104.6	104.4	78	81	75	72	120	72
6–20	105.0	104.8	104.4	84	72	84	66	138	102
6–21	104.2	105.1	104.8	78	78	75	66	138	108
6–22	104.4	104.7	104.4	69	72	78	54	108	60
6–23	104.3	104.7	104.6	78	78	81	114	80	80
6–24	103.6	104.3	104.0	75	84	75	60	108	126
6–25	103.8	103.7	104.6	81	72	78	102	66	132
6–26	104.2	104.5	104.8	78	75	84	102	60	108
6–27	103.4	103.8	104.0	78	75	72	96	102	84
6–28	103.2	103.6	104.2	69	66	72	36	120	126
6–29	103.8	103.4	103.9	78	75	72	96	90	60
6–30	103.7	103.3	103.5	72	54	66	54	60	42
7– 1	103.2	103.2	103.6	72	72	69	48	96	54
7– 2	103.6	103.6	103.6	78	78	66	72	84	48
7– 3	103.4	103.6	103.8	63	60	60	48	54	66
7– 4	102.9	103.3	103.5	66	72	75	42	84	54
7– 5	103.4	103.5	103.8	78	72	69	81	78	66
7– 6	103.8	103.6	103.0	78	72	69	114	66	84
7– 7	103.2	103.4	103.6	72	72	66	42	78	60
7– 8	103.3	103.4	103.4	66	66	66	60	90	72
7– 9	103.8	103.3	103.4	63	66	66	66	72	96
7–10	103.2	103.2	103.7	72	72	75	84	66	84
7–11	103.4	103.5	103.4	69	72	66	60	54	69
7–12	103.5	103.4	104.2	72	72	66	48	84	66

*Docked.

	Temperature.			Pulse.			Respiration.		
Date.	A.M.	M.	P.M.	A.M.	M.	P.M.	A.M.	M.	P.M.
7–13	104.3	103.8	103.9	66	66	72	72	72	60
7–14	103.4	103.6	104.0	66	69	75	48	48	84
7–15	103.3	103.0	103.5	66	66	60	42	78	66
7–16	103.3	103.0	103.9	66	66	66	48	54	96
7–17	103.3	103.4	103.3	66	72	72	72	90	66
7–18	102.3	103.0	102.8	66	60	66	42	48	60
7–19	103.0	103.0	102.5	60	60	57	54	48	36
7–20	102.6	102.3	103.0	63	57	54	42	48	54
7–21	102.4	102.7	103.0	60	60	60	42	54	54
7–22	103.4	103.3	102.8	66	63	66	66	42	66
7–23	103.4	103.8	103.3	66	66	63	42	54	48

This suckling lamb was unfortunately docked June 11, which accounts for the increased temperature, pulse, and respiration on that and several succeeding days.

Clinical Notes. The animal was put into the pen July 30, and was given 250 c.c. of expressed juice at 2:30 P. M. He refused supper and stood in a drooping posture. Next morning he ate about one-fourth pound of oats and was given another 250 c.c. of juice. In the evening, a third quantity of 250 c.c. of juice was given. He refused to eat in the afternoon. On August 1, breathing was accelerated and was accompanied by groaning. He refused all feed. He refused feed on the following day, gritted his teeth, breathing was jerky, and he appeared droopy. On August 3 he ate about one-fourth pound of oats and was more active, the symptoms having apparently subsided. He was given 250 c.c. of juice in the afternoon. On August 4 he refused the morning feed and 250 c.c. of juice were given. He ate all feed in the afternoon and was given another 250 c.c. of juice. On August 5 two doses of 250 c.c. each of juice were administered. A slight trembling was apparent on the morning of August 6 and he could stand without difficulty. No signs of trembling were noted in the afternoon, but he stood with head down and back bowed. He ate with normal appetite. Trembling was marked and no food was taken on August 7. In the afternoon the symptoms were more aggravated. A state of coma had set in during the following night, and on August 8 respirations were accelerated. This animal was killed on the morning of the 9th, having been in a state of coma since the night of the 7th.

Blood Study. On May 18 a blood study was made to determine the normal condition of the blood of this lamb prior to the commencement of the feeding test with white snakeroot. The following is the result:

Numerical count:

Erythrocytes	13,440,000
Leucocytes	10,000

Differential count:

Neutrophiles	27 per cent
Lymphocytes, large	5 per cent
Lymphocytes, small	66 per cent
Eosinophiles	1 per cent
Mast cells	1 per cent
Hemaglobin	75 per cent

On August 8 the lamb was very badly affected with trembles as a result of feeding expressed juice. The second blood study was made on this day. The results are as follows:

Numerical count:

Erythrocytes	16,800,000
Leucocytes	7,000

Differential count:

Neutrophiles	58 per cent
Lymphocytes, large	6 per cent
Lymphocytes, small	34 per cent
Mast cells	2 per cent
Eosinophiles	None
Hemaglobin	75 per cent

The hemaglobin remains normal and the eosinophiles disappear. There is an increase of the neutrophiles at the expense of the lymphocytes. There is a total decrease of the leucocytes and an apparent increase of the erythrocytes.

Urine Study. It was not possible to secure urine for examination before death. At autopsy a small quantity was collected through the natural passage by gentle pressure on the bladder. By the observance of this precaution, albumin from the peritoneal cavity cannot get into the urine. The result of the analysis is as follows:

Physical examination:
- Transparency—Cloudy.
- Specific gravity—1012.

Chemical examination:
- Reaction—Alkaline.
- Sugar—None.
- Albumin—Trace.
- Phosphates—Present.
- Chlorides—Present.
- Sulphates—Present.
- Carbonates—Present.

The excretion of chlorides, sulphates, and phosphates was normal and the presence of albumin alone can be regarded as an abnormality.

Protocol. The carcass presents the appearance of a normal lamb, there being no palpable lymph glands nor cutaneous and subcutaneous lesions.

The Thoracic Cavity.—The lungs are pale salmon pink in color and collapse when the thorax is opened. Neither pleuritis, pneumonia, nor bronchitis are noted. There is an excessive amount of liquid in the thoracic cavity.

The Heart—The heart is pale, flabby, and small petechiations are noted at the base along the coronary arteries. A small quantity of dark coagulated blood is found in the auricles, whereas the ventricles are empty. There is no antemortem clot.

The Abdominal Cavity.—There is no abnormal quantity of liquid in the peritoneal cavity. The intestines appear normal. There are no stomach worms in the abomasum and nodular disease and peritonitis are not present.

The Spleen is normal.

The Liver.—The liver is yellowish and when examined closely, the nutmeg appearance is found to be present. The liver is so gorged with blood that it drips from the sectioned surface. The gall bladder is full.

The Bladder contains a small quantity of cloudy urine and is slightly injected.

The Kidneys.—The kidneys have a metallic appearance. Active and passive congestion are present. The sectioned surface is pale, indicating cloudy swelling.

Microscopical Examination. *The liver* shows more or less active and passive congestion, although this condition is not so intense as in many of the other cases heretofore examined. Cloudy swelling and fatty degeneration are present.

The Kidneys.—Cloudy swelling is present. The cells of the convoluted tubules are swollen, the cytoplasm granular, and the lumina in many of the tubules are entirely obliterated. Many of the cells are in a state of necrosis. Fatty degeneration is noted in certain areas, involving the cells of the convoluted tubules. Glomerulitis is present.

The Heart.—Miescher's cysts are present. These are located in the cell substance, causing the cell wall to bulge outward. The nuclei of the heart muscle cells stain faintly. Fatty degeneration is not discernible.

The Lungs are normal.

The Pancreas is normal.

The Lymph Glands are normal.

CASE 4, TABLE X, SHOWING TEMPERATURE, PULSE, AND RESPIRATION OF LAMB 244.

	Temperature.			*Pulse.*			*Respiration.*		
Date.	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*
5–11	.....	.....	104.0	....	....	82	.....	.....	78
5–12	.....	.....	103.5	....	....	72	.....	.....	66
5–13	.....	103.0	.....	....	79	....	.....	68	.....
5–14	102.8	102.6	103.4	84	84	68	78	72	70
5–15	102.6	102.7	103.2	72	84	72	70	78	120
5–16	103.0	102.9	103.0	84	84	90	96	114	156
5–17	103.0	103.0	102.9	72	84	90	132	144	168
5–18	103.5	103.3	103.3	108	96	102	168	180	186
5–19	103.5	102.3	103.5	84	90	96	178	192	216
5–20	103.9	103.1	103.5	84	90	96	192	192	204
5–21	103.3	103.1	103.5	78	90	90	168	174	174
5–22	103.6	103.3	103.6	90	90	84	150	162	210
5–23	103.8	103.5	103.6	78	84	72	114	132	144
5–24	103.6	102.8	103.2	72	72	72	156	116	132
5–25	103.4	103.0	102.9	72	84	90	108	144	144
5–26	102.9	103.2	103.0	84	84	84	54	108	132
5–27	103.4	103.1	103.3	72	90	72	120	132	138
5–28	103.4	103.4	103.1	84	87	90	114	144	108
5–29	102.8	.....	103.0	72	....	84	84	.....	90
5–30	103.0	102.8	102.8	84	78	84	78	102	150
5–31	102.6	103.0	103.0	78	78	72	78	96	84
6– 1	103.2	103.2	103.4	84	84	84	132	144	156
6– 2	103.2	103.2	103.5	78	72	84	126	150	136
6– 3	104.1	103.8	103.9	84	81	84	144	132	156
6– 4	103.0	103.4	103.6	87	84	78	84	102	126
6– 5	103.5	103.4	103.2	78	84	78	120	132	120
6– 6	103.7	103.7	104.0	81	75	81	102	144	150
6– 7	104.1	103.6	103.8	90	84	78	96	126	120
6– 8	104.0	104.0	104.2	81	81	78	126	132	120
6– 9	103.6	103.6	103.8	84	87	78	108	120	120
6–10	103.2	104.0	103.5	84	75	72	72	96	102
6–11	103.8	104.2	104.3	78	78	84	96	114	132*
6–12	104.2	105.0	104.6	75	78	78	126	144	192
6–13	104.8	104.7	104.8	69	72	72	192	180	192
6–14	105.4	105.6	105.1	75	69	66	192	198	168
6–15	105.6	105.5	105.8	72	66	60	150	168	168
6–16	106.0	106.4	106.5	66	72	78	120	102	126
6–17	106.4	107.0	.....	60	90	....	60	78	....

*Docked.

These data indicate that there was a disturbance in temperature after the onset of symptoms.

Clinical Notes. This lamb was given twice daily one-fourth pound of cracked corn and oats mixed, and one-half pound of kale. She was suckling the mother, ewe 171, who received twice daily three-fourths pound of cracked corn and oats mixed and one-fourth pound of white snakeroot. In addition to this, she received, at noon, one pound of hay and two pounds of kale.

A manifest stiffness of the limbs was apparent on June 11. On June 13, she refused grain and ate only a small amount of kale. She appeared stiff, droopy, and dull. In the afternoon, respirations were slightly jerky. On the morning of June 14, she trembled slightly and was prone to lie down at all times. When made to stand she would tremble, and the longer she was kept on her feet the more intense the trembling. In the afternoon the symptoms were more aggravated. She trembled in all parts of the body and after a paroxysm of trembling would fall down apparently exhausted. At intervals she gritted her teeth. On the 15th, while lying down, she attempted to eat kale. Trembling became more aggravated, as did the gritting of teeth, and she appeared weaker than on the previous day. She did not eat during the afternoon. On the morning of June 17 she was found prostrate on her side. Respiration was labored, eyes were set, and legs were intermittently trembling. She died about 12:30 P. M.

Blood Study. On May 18 a study was made of the blood of lamb 244 to determine the normal condition, with the following results:

Numerical count:	
Erythrocytes	13,560,000
Leucocytes	12,000
Differential count:	
Neutrophiles	20 per cent
Lymphocytes, large	7 per cent
Lymphocytes, small	71 per cent
Eosinophiles	1 per cent
Mast cells	1 per cent
Hemaglobin	75 per cent

On June 16, after the symptoms of milksickness had developed, another study was made. The results are as follows:

Numerical count:	
Erythrocytes	15,600,000
Leucocytes	10,000
Differential count:	
Neutrophiles	44 per cent
Lymphocytes, large	6 per cent
Lymphocytes, small	49 per cent
Mast cells	1 per cent
Hemaglobin	75 per cent

There was an increase of neutrophiles at the expense of the lymphocytes and an apparent increase in the erythrocytes. The lamb had refused water for at least forty-eight hours before this second study was made, which may account for the apparent increase. The eosinophiles had entirely disappeared. The hemaglobin remained the same.

Urine Study. On June 17, when the autopsy was made, the urine was forced out of the normal outlet by gentle pressure upon the bladder and was thus kept free from albuminous material. The following is the result of the analysis:

Physical examination:
- Sediment—Present.
- Transparency—Cloudy.
- Specific gravity—Insufficient amount for test.

Chemical examination:

Phosphates—Present.	Chlorides—Present.
Reaction—Faintly acid.	Albumin—None.
Sugar—None.	Carbonates—Present.
	Sulphates—Present.

The urine of suckling lambs is normally acid in reaction. The cloudy condition is noted in other cases of milksickness. The lamb was apparently normally eliminating the phosphates, chlorides, and sulphates.

Protocol. There are no subcutaneous nor cutaneous lesions to be found. There are no palpable lymph glands, and the external appearance is that of a normal lamb.

Thoracic Cavity.—The lungs do not collapse when the thorax is opened. There is present a congestive condition, but neither pneumonia, bronchopneumonia, nor pleuritis. The lungs are dark pink in color.

The Heart.—Petechiation at the the base of the heart along the course of the coronary arteries is noted. The right side of the heart is empty, while the left contains dark coagulated blood. There are no petechiations on the endocardium or pericardium.

The Abdominal Cavity.—There is no abnormal quantity of fluid in the abdominal cavity. There is no peritonitis. The small and large intestines are affected with nodular disease and stomach worms are present in small numbers in the abomasum. The small intestine appears injected, which condition does not exist in the large intestine.

The Spleen.—Normal.

The Kidneys.—The kidneys appear swollen and of a metallic appearance. The capsule strips off easily. Both active and passive congestion and cloudy swelling are present. Both kidneys weigh one-eighth pound.

The Musculature.—The musculature appears normal.

The Liver.—The liver is filled with blood which drips from the sectioned surface. It is nutmeg in appearance. There is evidence both of congestion and of cloudy swelling. The liver weighs one-fourth pound.

The Lymph Glands.—The lymph glands appear normal.

The Brain.—The brain appears somewhat congested.

Microscopical Examination. *The Liver.*—After hardening in formalin, sectioning, staining with hematoxylon and eosin, and clarifying in beechwood creosote, study was made of the cellular changes.

The liver shows both active and passive congestion and cloudy swelling.

The Kidneys.—Active and passive congestion are present. There is an occasional area infiltrated with polymorphonuclear leucocytes and with a few round cells. Cloudy swelling in various stages is present, thus indicating an acute parenchymatous nephritis.

The Heart.—The blood vessels are congested. There is present no fatty degeneration.

The Brain.—The cerebrum and cerebellum are both congested. The brain cells appear normal with no invasion by leucocytes.

The Lungs.—The lung tissue shows congestion, certain alveoli are filled with serum and an occasional one with a few erythrocytes.

The Pancreas—Normal.

The Spleen.—Normal.

The Adrenal Glands.—Normal.

CASE 5, TABLE XI, SHOWING TEMPERATURE, PULSE, AND RESPIRATION OF EWE 12.

	Temperature.			*Pulse.*			*Respiration.*		
Date.	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*
5–11	.....	.....	103.3	....	....	68	.....	.....	72
5–12	.....	.....	104.0	....	....	65	.....	.....	60
5–13	.....	101.4	.....	....	56	....	.....	48	.....
5–14	101.0	101.2	102.2	58	66	48	52	45	30
5–15	100.5	101.2	101.9	60	54	66	42	42	42
5–16	101.3	102.0	102.1	56	70	66	48	48	54
5–17	101.5	102.0	103.0	66	66	66	36	42	54
5–18	101.4	101.8	102.6	72	76	72	48	54	72
5–19	101.8	101.9	102.7	60	63	72	48	48	78
5–20	102.0	102.0	101.9	66	72	72	42	45	45
5–21	101.9	102.2	103.2	69	66	72	39	48	90
5–22	102.0	101.9	102.9	72	60	69	36	42	72
5–23	101.8	101.6	102.4	57	66	60	33	48	42
5–24	101.5	101.6	102.2	66	60	63	30	36	36
5–25	101.6	101.4	102.3	54	63	66	30	36	36
5–26	102.0	102.2	103.0	63	66	69	30	27	35
5–27	102.0	102.3	103.2	72	72	75	30	42	84
5–28	102.3	102.2	103.4	72	63	72	30	48	48
5–29	101.8	.....	102.6	66	....	66	42	.....	36
5–30	101.5	101.5	102.3	69	60	69	42	38	42
5–31	101.2	101.6	102.4	69	72	60	39	48	36
6– 1	101.7	102.6	103.6	69	66	78	36	54	84
6– 2	103.0	102.5	103.0	66	72	78	33	48	66
6– 3	103.1	102.8	102.8	66	66	69	54	51	60
6– 4	102.2	102.4	102.6	60	66	66	36	36	30
6– 5	102.3	102.5	103.8	66	66	72	36	23	48
6– 6	102.0	102.0	103.3	72	66	66	42	39	84
6– 7	102.3	102.6	103.8	60	66	63	36	42	54
6– 8	102.2	102.6	103.4	69	66	66	36	42	30
6– 9	101.8	102.2	102.0	60	66	69	30	36	36
6–10	102.0	102.0	102.7	66	66	60	27	30	27
6–11	101.5	101.8	103.7	72	69	66	30	27	48
6–12	101.6	102.6	103.5	69	60	66	36	48	72
6–13	102.2	103.0	103.4	63	72	68	36	66	54
6–14	102.4	102.0	103.1	72	72	66	30	75	30
6–15	102.2	102 8	103.4	72	69	72	42	36	48
6–16	102.7	102.4	103.0	69	69	72	30	30	42
6–17	102.2	102.2	103.0	72	66	63	42	66	42
6–18	102.0	102.0	104.0	66	72	66	42	36	48
6–19	102.6	102.6	102.8	69	75	66	39	84	60
6–20	102.7	102.7	103.0	66	66	69	45	60	57
6–21	102.2	103.2	103.4	66	72	66	54	60	72
6–22	102.7	102.5	102.7	72	66	66	39	48	54
6–23	102.8	103.3	103.4	66	72	69	63	78	72
6–24	102.0	102.4	103.8	72	66	78	54	72	120
6–25	102.8	103.0	103.2	63	66	66	42	72	72
6–26	102.6	102.5	103.7	60	72	72	42	60	102
6–27	102.8	102.6	103.2	72	69	69	48	72	84
6–28	102.6	102.6	103.6	66	60	69	42	54	78
6–29	102.7	102.6	102.8	69	69	72	48	54	36
6–30	102.4	102.0	103.2	69	63	69	36	54	72
7– 1	103.0	102.7	102.4	66	66	69	48	54	72
7– 2	102.6	102.5	103.0	75	72	66	36	60	48
7– 3	102.5	102.6	103.3	72	69	66	42	54	72
7– 4	101.6	102.4	102.5	72	72	69	42	63	74
7– 5	102.1	103.0	103.3	66	72	69	36	60	54
7– 6	102.6	102.8	103.0	72	69	63	42	66	54
7– 7	102.6	102.6	102.8	60	69	66	48	54	42
7– 8	102.3	103.0	102.3	66	72	69	54	60	72
7– 9	102.6	103.0	103.3	72	66	72	54	60	96
7–10	102.8	102.9	103.4	72	69	69	54	66	72
7–11	102.6	103.2	103.7	72	66	72	48	78	66
7–12	103.4	103.3	103.4	63	69	66	48	66	90
7–13	102.3	102.9	103.4	66	66	72	54	54	66
7–14	103.0	103.1	103.5	72	66	69	42	66	78
7–15	103.0	103.0	103.2	72	66	63	36	69	66
7–16	102.7	102.6	103.2	66	66	66	48	60	108
7–17	102.6	103.0	103.2	72	72	69	36	90	72
7–18	101.5	102.5	102.7	66	60	60	48	42	54
7–19	101.5	102.2	103.5	69	66	84	72	78	60
7–20	101.3	101.7	102.7	69	78	78	66	54	69
7–21	101.1	101.9	101.9	78	72	75	90	84	84
7–22	102.0	102.1	102.4	72	81	78	60	72	63
7–23	102.5	102.3	102.3	72	69	66	60	60	54

These data do not show any variation from the normal in temperature, pulse, or respiration.

Clinical Notes. On July 17 ewe 12 appeared droopy, dull, and stood with eyes half-closed. On the 19th breathing was jerky and trembling was noted in both fore and hind limbs. After she had lain quiet for a while she would stand for several minutes, and with the onset of trembling would lie down again. Her appetite was good. On July 21 the symptoms were more aggravated. She would stand with all four feet close together under the body, with back arched, and was quite stiff. On the 22d, trembling was more violent, but her appetite remained good. In the afternoon, she passed into a comatose condition. There was little appreciable change on July 23, but the symptoms were more aggravated. On July 24 she was killed and an autopsy was performed.

It should be noted with reference to this ewe that she had recovered from trembles from feeding experiments of the previous year. This indicates that one attack does not render immunity to a subsequent attack, a fact in keeping with popular belief.

Blood Study. On May 18 a study was made of the blood of ewe 12 to determine its normal condition. The following is the result:

Numerical count:	
Erythrocytes	8,240,000
Leucocytes	12,000
Differential count:	
Neutrophiles	47 per cent
Lymphocytes, large	7 per cent
Lymphocytes, small	40 per cent
Eosinophiles	3 per cent
Mast cells	None
Hemaglobin	70 per cent

On July 22, after symptoms of trembles had become well developed, another blood study was made with the following result:

Numerical count:	
Erythrocytes	8,320,000
Leucocytes	5,000
Differential count:	
Neutrophiles	66 per cent
Lymphocytes, large	8 per cent
Lymphocytes, small	22 per cent
Eosinophiles	None
Mast cells	4 per cent
Hemaglobin	75 per cent

There was an increase of neutrophiles at the expense of the small lymphocytes. There was a disappearance of the eosinophiles and the appearance of mast cells. The hemaglobin remained practically the same and there was no change in the number of erythrocytes. There was a considerable decrease in the leucocytes.

Urine Study. An analysis of the urine was made on June 18, with the following results:

Physical examination:

Transparency—Pale straw color.

Specific gravity—1014.

Chemical examination:
Reaction—Alkaline.
Sugar—Present.
Albumin—Present.
Phosphates—Present.
Carbonates—Present.
Chlorides—Present.
Sulphates—Present.

On July 19, after the symptoms of trembles were well developed, the urine was again analyzed. The following is the result of this analysis:

Physical examination:
Transparency—Brownish yellow.
Sediment—Present.
Specific gravity—1030.

Chemical examination:
Reaction—Neutral.
Sugar—Present.
Albumin—Present.
Carbonates—Present.
Sulphates—Present.
Chlorides—Present.
Phosphates—Present.

Microscopic examination:
Tube casts—Present.
Character of casts—Granular (Fig. O).
Epithelial cells—Round, squamous, elliptical.

Protocol. Externally the body presents nothing on inspection that is to be considered worthy of note. There are no subcutaneous lesions of any kind to be found.

Thoracic Cavity.—There is no pleuritis. The lungs do not collapse when the thorax is opened. The color of the lungs is a purplish-salmon. No edema, pneumonia, nor broncho-pneumonia are present. No ecchymoses are found on the pleural surface.

The Heart.—There is slightly more fluid than is normal in the pericardial sac. Small petechial areas occur over the base of the heart. There is no pericarditis nor endocarditis. The right side of the heart is empty and the left side contains dark, coagulated blood, post mortem coagulation. The heart muscles appear pale.

The Abdominal Cavity.—There is no abnormal quantity of fluid in the abdominal cavity. The small and large intestines are affected with nodular disease. Few stomach worms are to be found in the abomasum. The small intestine is highly injected and the large intestines appear normal in this respect.

The Spleen.—Normal.

The Kidneys.—The kidneys appear swollen, the capsule having a metallic appearance. Both active and passive congestion are discernible. Cloudy swelling is present. Both kidneys weigh four and one-half ounces.

The Liver.—The liver shows the characteristic discoloration and blood flows freely from the sectioned surface.

The bladder.—The bladder is injected and contains a small quantity of urine.

Museulature.—The musculature is normal in appearance.

The Brain.—The brain, as well as the coverings, appear congested.

The Lymph Glands.—All visceral and body lymph glands appear normal.

Microscopical Examination. *The Liver.*—The tissues were first hardened in formaldehyde, sections were then made, which were stained in hematoxylon and eosin, and clarified in beechwood creosote.

The liver shows both active and passive congestion, cloudy swelling and fatty degeneration.

The Kidneys.—The kidneys show both active and passive congestion. Cloudy swelling and glomerulitis are present. Some of the cells of the convoluted tubules have lost their nuclei and are in a state of necrosis. In some areas the lumina are not discernible and the bases of the cells have separated, the whole mass pushing toward the center. Some of the tubules show evidence of fatty degeneration.

The Brain.—The blood vessels are congested. An occasional polymorphonuclear leucocyte and quite a number of plasma cells are in each microscopic field. The brain cells appear normal and are not shrunken.

The Heart.—The heart muscle fibers have lost their cross-striation. Many parts show fatty degeneration. The nuclei stain deeply, in fact, are picnotic. The blood vessels are congested.

The Lungs.—The lungs are hyperemic. Some alveoli are filled with serum. There is no bronchitis nor pneumonia.

The Duodenum.—Much round-celled infiltration and hyperemia are evident.

The Panereas.—Normal.

The Adrenal Gland.—Normal.

CASE 6, TABLE XII, SHOWING TEMPERATURE, PULSE, AND RESPIRATION OF LAMB 237.

	Temperature.			*Pulse.*			*Respiration.*		
Date.	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*
5–11	.....	.....	104.6	....	....	70	.....	.....	72
5–12	.....	.....	103.6	....	....	72	.....	.....	72
5–13	.....	103.8	.....	....	76	....	.....	84	.....
5–14	102.7	101.8	103.0	78	78	48	60	72	60
5–15	104.2	104.1	103.5	84	90	72	84	108	108
5–16	102.1	102.7	103.1	84	72	78	72	78	96
5–17	102.3	102.3	103.0	78	80	84	90	102	144
5–18	102.6	103.0	102.7	78	80	78	144	156	150
5–19	102.9	102.6	102.9	80	84	78	178	190	198
5–20	102.5	102.1	102.5	90	90	84	180	186	182
5–21	103.1	103.2	103.4	78	78	84	193	163	144
5–22	102.6	102.8	103.5	78	90	84	138	162	156
5–23	103.2	103.0	103.0	90	84	78	126	144	120
5–24	102.8	102.6	103.2	78	84	78	84	102	96
5–25	103.0	103.2	103.0	72	75	78	108	108	108
5–26	103.0	102.8	103.2	84	75	84	90	102	102
5–27	103.4	103.0	103.2	75	75	78	84	114	108
5–28	103.4	102.9	103.0	72	66	72	102	78	72
5–29	103.0	.....	102.9	72	....	84	66	.....	60
5–30	103.2	103.0	103.1	72	69	75	60	108	120
5–31	102.6	102.5	102.8	78	84	78	72	78	102
6– 1	103.4	103.1	103.8	84	78	78	120	147	144
6– 2	102.8	103.0	103.0	72	84	72	126	132	132
6– 3	103.5	103.7	103.6	81	78	84	156	138	120
6– 4	102.8	103.0	103.2	72	84	72	66	69	96
6– 5	103.2	103.0	103.2	81	72	75	102	120	114
6– 6	103.4	103.2	103.6	72	81	75	102	108	108
6– 7	103.6	103.0	104.2	72	78	84	108	96	120
6– 8	103.4	103.2	103.6	75	72	72	108	120	108
6– 9	103.0	103.6	103.5	72	72	75	84	108	84

	Temperature.			Pulse.			Respiration.		
Date.	A.M.	M.	P.M.	A.M.	M.	P.M.	A.M.	M.	P.M.
6–10	103.4	103.8	103.7	72	72	75	48	75	54
6–11	103.2	103.0	104.5	78	78	81	48	84	108
6–12	103.8	103.5	103.8	84	75	72	126	120	132
6–13	104.1	104.0	104.2	75	78	72	120	126	144
6–14	104.0	104.0	103.3	78	75	75	108	120	90
6–15	103.6	103.5	104.0	78	78	78	66	60	84
6–16	103.0	103.8	104.0	78	78	72	60	54	60
6–17	103.4	103.3	104.1	78	72	72	66	78	72
6–18	102.8	103.4	104.1	75	75	72	78	102	96
6–19	103.6	103.7	104.0	78	78	75	84	90	114
6–20	103.4	103.9	104.2	72	72	72	90	84	96
6–21	104.0	104.1	104.4	78	75	72	84	96	102
6–22	103.7	103.5	103.8	72	72	75	78	108	96
6–23	104.4	103.3	104.4	78	75	78	84	108	104
6–24	104.0	104.2	104.6	78	75	75	90	120	144
6–25	104.1	104.2	104.4	66	75	72	126	126	144
6–26	103.6	103.9	104.6	69	72	81	78	120	120
6–27	104.6	104.5	105.0	78	72	72	120	138	126
6–28	104.6	104.4	104.0	78	78	72	90	108	114
6–29	104.0	104.1	104.0	75	72	72	90	102	66
6–30	103.8	103.4	104.0	72	72	78	72	96	102
7– 1	103.7	104.0	104.2	69	69	72	78	108	78
7– 2	104.2	103.8	103.0	72	75	72	90	99	78
7– 3	103.2	103.7	103.4	69	66	54	60	66	66
7– 4	103.0	103.6	103.8	72	69	60	66	90	90
7– 5	103.9	103.5	103.8	81	72	66	90	96	120
7– 6	104.2	103.6	103.4	72	66	72	78	60	84
7– 7	103.6	103.6	103.7	69	66	72	66	42	72
7– 8	103.9	103.3	103.6	60	69	60	48	84	72
7– 9	104.0	103.6	104.2	66	69	66	90	96	90
7–10	103.3	103.8	104.7	66	63	72	60	102	120
7–11	103.8	103.8	104.0	69	66	78	72	54	66
7–12	103.8	103.7	104.1	60	66	69	72	96	78
7–13	103.8	103.5	103.8	72	66	69	51	72	84
7–14	103.8	103.5	103.8	66	66	72	48	102	114
7–15	104.1	103.9	104.2	66	66	72	60	90	96
7–16	104.1	103.9	104.2	63	60	66	54	60	96
7–17	104.0	104.0	103.8	66	69	66	96	96	72
7–18	103.5	103.4	103.6	60	63	66	54	60	66
7–19	103.2	103.8	104.2	63	66	57	48	54	48
7–20	103.0	103.7	103.1	66	66	60	72	57	42
7–21	102.7	103.0	103.8	57	60	63	48	51	54
7–22	104.1	104.3	103.7	69	66	66	60	84	84
7–23	104.0	104.1	104.5	60	60	60	66	84	96
7–24	104.0	104.4	104.1	66	69	66	78	114	84

Clinical Notes. On July 30 at 2:30 P. M. lamb 237 was taken from the pasture, placed in the experimental pen and given 500 c.c. of expressed juice. He refused his feed in the evening. Next morning breathing was short and labored and he gritted his teeth. He ate about one-fourth pound of oats and was given 500 c.c. more of juice. At 3 P. M. a third quantity of 500 c.c. was given. He refused his feed in the evening. On the morning of August 1 he was found dead.

Protocol. The external appearance of the carcass is that of a normal lamb.

The Thoracic Cavity.—Neither pleuritis nor pneumonia is present. The lungs are a pale salmon color and collapse when the thoracic cavity is opened.

The Heart.—There is no excessive fluid in the pericardial sac. A small amount of coagulated dark blood is found in the left side, the right being empty. The heart muscle appears normal.

The Abdominal Cavity.—The abdominal cavity does not contain an excessive amount of fluid and there is no peritonitis present. The bladder is empty and appears normal. The stomach and small and large intestines appear normal. Neither nodular disease nor stomach worms are present.

The Spleen.—Normal.

The Musculature.—Normal.

The Brain.—Normal.

The Lymph Glands—Normal.

The Liver.—The liver appears normal in color and size. The gall bladder is full.

The Kidneys.—The capsule has a metallic appearance and can easily be stripped off. Both active and passive congestion are evidenced. The grayish appearance of the parenchyma also gives evidence of cloudy swelling.

Microscopical Examination. *The Liver.*—Active and passive congestion and cloudy swelling are present.

The Kidneys.—Glomerulitis and cloudy swelling are present. In some areas the nuclei take little or no stain and in others the cells have lost their nuclei. The lumina in these areas are occluded and many cells are thus in a state of necrosis. Some cells are in a state of picnosis. Certain of the tubules show fatty degeneration.

The Pancreas.—Normal.

The Adrenal Glands.—Normal.

The Lungs.—Normal.

The Heart.—Normal.

CASE 7, TABLE XIII, SHOWING TEMPERATURE, PULSE, AND RESPIRATION OF LAMB 242.

	Temperature.			*Pulse.*			*Respiration.*		
Date.	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*	*A.M.*	*M.*	*P.M.*
5–11	.....	.....	104.6	....	....	67	.....	.....	42
5–12	.....	.....	104.0	....	....	66	.....	.....	72
5–13	.....	103.0	.....	....	84	....	.....	72	.....
5–14	102.8	102.4	102.7	76	80	66	72	78	42
5–15	102.6	102.9	103.1	63	78	78	60	66	96
5–16	102.3	102.6	103.1	60	72	96	48	63	90
5–17	103.1	102.6	102.6	78	96	86	78	114	120
5–18	103.1	103.0	103.0	96	96	96	138	172	180
5–19	103.6	103.6	103.1	78	84	90	150	160	192
5–20	103.0	102.7	102.8	78	90	90	144	150	163
5–21	103.4	102.8	103.3	84	84	96	168	144	168
5–22	103.6	102.8	103.4	84	84	72	156	150	162
5–23	103.4	103.2	103.5	78	90	84	120	138	144
5–24	103.0	102.8	103.0	78	72	84	114	102	108
5–25	103.0	103.0	103.2	78	71	87	120	138	132
5–26	103.0	103.8	103.8	78	90	90	90	120	150
5–27	103.0	102.4	103.2	84	90	87	123	152	150
5–28	103.2	103.2	103.1	90	75	84	138	126	108
5–29	103.0	.....	102.9	84	....	84	96	.....	90
5–30	102.7	102.6	103.3	90	84	84	96	102	108
5–31	102.8	103.0	103.0	90	78	78	72	96	114
6– 1	103.3	103.4	103.4	69	78	90	102	144	150
6– 2	103.1	103.0	103.9	81	78	90	126	132	114
6– 3	103.3	103.0	103.9	81	90	87	138	120	168
6– 4	102.7	103.0	103.7	78	84	84	84	96	102
6– 5	103.2	102.9	102.8	78	78	75	78	132	102
6– 6	103.5	103.7	104.0	87	72	87	132	150	162
6– 7	103.9	103.6	104.2	84	78	81	126	120	144
6– 8	104.2	103.8	103.8	81	87	90	132	138	124
6– 9	103.6	103.2	103.9	84	78	84	108	120	132
6–10	103.4	103.6	103.5	81	84	72	72	96	78
6–11	103.3	103.5	104.2	81	84	78	90	126	138*
6–12	104.2	104.2	105.1	78	78	72	150	156	144
6–13	104.1	104.7	105.3	78	84	84	132	150	162
6–14	105.8	105.6	105.4	72	72	84	192	180	132
6–15	105.0	105.0	105.1	69	72	66	60	114	138
6–16	105.9	106.2	Died	66	66	....	108	60	.....

*Docked.

Clinical Notes. On the morning of June 13 there was a manifest stiffness of the legs. The next day the lamb stood with head down and back bowed. On the 15th she did not touch the kale or grain and upon being exercised

began to tremble. She did not remain long on her feet, but lay down as though exhausted. Trembling was aggravated with the additional symptoms of vomiting, frothing at the mouth, grating of the teeth, and labored breathing on the 16th. She died at 1:30 P. M.

Blood Study. On May 18 a study was made of the blood to determine the normal condition of this lamb's blood with the following result:

Numerical count:	
Erythrocytes	13,040,000
Leucocytes	14,000
Differential count:	
Neutrophiles	20 per cent
Lymphocytes, large	16 per cent
Lymphocytes, small	61 per cent
Eosinophiles	3 per cent

On June 15, after the symptoms had developed, another study of the blood was made with the following results:

Numerical count:	
Erythrocytes	14,000,000
Leucocytes	11,000
Differential count:	
Neutrophiles	46 per cent
Lymphocytes, large	2 per cent
Lymphocytes, small	52 per cent
Eosinophiles	None

This shows an increase of neutrophiles with a corresponding decrease of lymphocytes. The eosinophiles have disappeared. There is a decrease in the total number of leucocytes, and apparently a slight increase of erythrocytes.

Protocol. There are no cutaneous or subcutaneous lesions to be found. The lymph glands are not palpable and the external appearance is that of a normal lamb.

The Thoracic Cavity.—The lungs are of pale salmon color and collapse when the thorax is opened. There is present neither pneumonia nor pleuritis.

The Heart.—The heart weighs one-fourth pound. It shows small petechiæ along the course of the coronary arteries. The heart muscle appears normal.

The Abdominal Cavity.—The quantity of fluid in the abdominal cavity is normal and there is no peritonitis. The small and large intestines appear normal.

The Spleen.—Normal.

The Musculature.—Normal.

The Kidneys.—The kidneys are very dark in color and the surface appears slightly mottled, due to intense congestion. Both active and passive congestion are present. The sectioned surface is grayish, indicating cloudy swelling. Both kidneys weigh one-eighth pound. The capsule strips off easily.

The Adrenal Glands.—Normal.

The Lymph Glands.—Normal.

The Liver.—The liver is normal in color. It weighs one and one-eighth pounds. The gall bladder is full.

The Brain.—The coverings and brain substance are normal in appearance.

Microscopical Examination. *The Liver.*—Fatty degeneration, active and passive congestion and cloudy swelling are present.

The Kidneys.—Active and passive congestion are present. The nuclei of the parenchymatous cells, in some areas, are picnotic; in others, they stain faintly. The protoplasm is granular and the cells swollen. The lumina of certain tubules are partially occluded and in some places the lumina of the convoluted tubules have disappeared. The nuclei, especially of these convoluted tubules, have entirely disappeared and the cells are in a state of necrosis. Many of the glomerules appear shrunken and a wide space can be noted between the capillary plexus and the capsule of Bowman. Thus acute parenchymatous nephritis with glomerulitis and active and passive congestion are present.

The Heart.—The blood vessels are congested.

The Brain.—The brain is congested. This congestion involves both arteries and veins. The spinal cord also shows congestion.

The Lungs.—Normal.

The Pancreas.—Normal.

The Adrenal Gland.—Normal.

The following microscopic studies were made of the livers and kidneys of six guinea pigs:

Microscopical Examination. CASE 1.—Acid extract, No. 1.

Liver.—Congestion, fatty degeneration, and cloudy swelling are marked. Congestion, both active and passive, is more intense than in sheep.

Kidneys.—The changes in the kidneys include active and passive congestion, fatty degeneration, and cloudy swelling.

CASE 2.—Green stems, No. 2.

Liver.—Cloudy swelling, fatty degeneration, and active and passive congestion are all present. An occasional area is invaded by polymorphonuclear leucocytes.

Kidneys.—The metamorphoses include active and passive congestion, cloudy swelling, and glomerulitis.

CASE 3.—Green leaves.

Kidneys.—Glomerulitis, active and passive congestion, and cloudy swelling are very pronounced.

Liver.—Active and passive congestion and cloudy swelling are present. There are fatty degenerative changes in some areas.

CASE 4.—Expressed juice, No. 1.

Liver.—Active and passive congestion and cloudy swelling are apparent. There are, furthermore, areas showing the beginnings of fatty degeneration.

Kidney.—The pathological changes include active and passive congestion, cloudy swelling, and glomerulitis.

Cultural studies were made of the blood from the liver, kidneys, and heart. Three tubes of agar were inoculated and all except one were negative. In this tube, a polar staining, short bacterium was isolated in pure culture. Intraperitoneal inoculation on guinea pigs resulted in no evidence of disease. The germ in question was, therefore, considered as a contamination.

CASE 5.—Expressed juice, No. 2.

Liver.—Cloudy swelling and fatty degeneration are present. This liver does not show active or passive congestion.

Kidneys.—Active and passive congestion are present. Cloudy swelling is well advanced in the convoluted tubules, in many of which the cells are in a state of disintegration.

CASE 6.—Green leaves, No. 2.

Liver.—Fatty degeneration was more advanced than in Case 4. Active and passive congestion are present.

Kidneys.—Active and passive congestion and cloudy swelling are seen in the renal tissues. Some of the convoluted tubules show fatty degeneration.

The following report covers the clinical examination of one hog which died during the feeding experiments:

Urine Study. An analysis of the urine shows the reaction to be acid. The specific gravity is 1014. Tests for albumin and sugar were negative.

Protocol. There are no subcutaneous or cutaneous lesions to be found, and no palpable lymph glands. The external appearance presents the picture of a young hog in a poor condition of flesh. The conjunctiva are pale.

Thoracic Cavity.—The lungs do not collapse when the thorax is opened, and certain of the lobules show congestion. When the sectioned surface of the lungs is examined, the bronchi are found to contain a frothy material.

The Heart.—The heart muscle appears pale, but there is no petechiation. There is present a slight evidence of a hydropericardial condition, and the pleura is normal.

The Abdominal Cavity.—The peritoneum, spleen and lymph glands are normal. The liver presents a pale, parboiled appearance, the lobules show very distinctly, and from the sectioned surface can be scraped a material which has the appearance of fat, and ignites when held in a flame. Duodenitis is present.

The Kidneys.—The kidneys appear normal in size and are of the same parboiled appearance as was noted in the case of the liver.

The Bladder.—Filled with urine.

The Musculature.—The general musculature of the body appears paler than normal.

Microscopical Examination. *The Liver.*—The liver shows both cloudy swelling and fatty degeneration in rather advanced stages.

The Kidneys.—Fatty degeneration is evident as are also various stages of cloudy swelling.

The Heart.—The nuclei stain pale, but the muscle cells have not lost their cross-striation.

The Brain.—The brain, both cerebrum and cerebellum, appear normal.

The Lungs.—Some lobules show edema and congestion.

The Pancreas.—Normal.

The Spleen.—Normal.

The Adrenal Glands.—Normal.

Cultural Examination. No growth appeared in attempted isolations of organisms from the blood of the kidney and liver of this animal.

SUMMARY OF LESIONS

The following is a tabulation of the lesions of sheep and lambs dead of trembles and milksickness, from a total of 16 cases:

Gross	*No.*	*Per cent*
Petechia, epicardium	13	81
Pale heart muscle	3	18
Muco-enteritis, small intestine	12	75
Active and passive congestion, kidneys	15	93
Cloudy swelling, kidneys	15	93
Congestion of brain and meninges	6	37
Lungs do not collapse, slight edema	5	31
Congestion, liver	12	75
Cloudy swelling, liver	12	75
Hydropericardium*	4	25

The following is a tabulation of the microscopic study of the organs of 16 sheep and lambs dead of trembles:

Microscopic		
Liver:	*No.*	*Per cent*
Active congestion	9	56
Passive congestion	8	50
Cloudy swelling	13	81
Fatty degeneration	14	87
Kidneys:		
Active congestion	8	50
Passive congestion	7	43
Cloudy swelling	16	100
Glomerulitis	9	56
Fatty degeneration	5	31
Brain:		
Congestion†	8	50
Heart:		
Fatty degeneration	5	31
Congestion	4	25
Lungs:		
Hyperemia	5	31
Edema	4	25
Duodenum:		
Muco-enteritis	12	75

The most striking pathological features in trembles or milksickness are therefore the albuminoid and fatty metamorphoses of the parenchymatous organs.

*These sheep were infested with Hemonchus contortus, which may account for any hydropericardium present.

†Only twelve cases were studied microscopically.

Cultures were made from livers, hearts, and kidneys of a total of six sheep and lambs and one hog dead of the disease, all of which cultures were negative. Cultures were made from the heart, liver and kidneys of a guinea pig dead of the disease, one of which cultures showed a growth, which organism later proved to be a contamination.

Nature of the Poisonous Principle

Since a relatively recent claim has been made (Moseley, 1909) that the feeding of aluminium phosphate is followed by effects similar to those following the feeding of white snakeroot, an attempt was made in 1916 to produce trembles by feeding aluminium phosphate to sheep. Two ewes, 166 and 167, were accordingly maintained on this experiment from September 9 to November 17. During this time each ewe was fed 412 gm. of aluminium phosphate ($Al\ PO_4$; Baker's C. P.) mixed with 68.5 pounds of grain, this being supplemented with 138 pounds of alfalfa hay. The daily amounts of aluminium phosphate given were gradually increased from 2 to 16 gm.

At no time during this period of 69 days were these ewes observed to manifest any symptoms of trembles. The initial weight of ewe 166 was 80 pounds, and her weight at the close of the experiment was 91 pounds. The initial and final weights of ewe 167 were 90 and 93 pounds, respectively.

These results indicate that aluminium phosphate is not the active principle in white snakeroot and are in accord with statements more recently made by Moseley (1917).

Certain of the experiments with sheep and guinea pigs which were made in 1917 indicate a number of points with reference to the nature of the active substance in the production of trembles and milksickness. No evidence has been obtained that it is water soluble, or alcohol soluble, and evidence of its solubility in dilute acid is inconclusive. With long desiccation at a temperature of about 100 degrees C., the substance seems to lose its toxicity. Such is not the case when the expressed juice is evaporated at about 60 degrees C. The plant furthermore contains a nontoxic volatile oil which does not pass into the milk; at least it has not been possible in the several attempts which have been made to distil it from milk from a cow fed on white snakeroot. There is furthermore present a considerable amount of resinous material which, according to a recent account by Moseley (1917), exists in the leaves to the extent of 9 per cent of their dry weight and is the poisonous principle. This claim, however, is not supported by conclusive experimental data.

A number of the more common reagents for alkaloids were employed on the presumption that the plant contains an alkaloid, which is the active principle. No precipitate appeared when Mayer's reagent was added to expressed sap. Potassium ter-iodide, phosphotungstic acid, auric chlorid and platinic chlorid failed to yield precipitates. With a saturated solution of tannic acid, however, a copious precipitate appeared. Since many organic substances are precipitated with tannic acid, and since negative results were secured with all of the other common precipitants, there is little likelihood of the presence of an active alkaloid in white snakeroot.

Since the glucosides, eupatorin and euparin, are known to occur in Eupatorium perfoliatum and E. purpureum respectively, two species commonly present within the State, and since certain glucosides are known to possess toxicological properties, Bourqelot's general group test for the presence of reducing sugars after hydrolysis was made. A quantity of the expressed sap of the plant was made acid by the addition of 1 per cent by volume of concentrated hydrochloric acid and permitted to stand for twenty hours before analysis. Another portion was kept for an equal period of time at about 30 degrees C. to favor activity by enzymes within the sap. A third quantity was freshly expressed when needed for analysis. One hundred cubic centimeters of each sample were diluted with 400 c.c. of water, clarified with alumina cream and an aliquot, then taken for analysis. The official method* for the estimation of reducing sugars was followed. The results of this analysis showed the presence of approximately .10 gm. of reducing sugar in 100 c.c. of freshly prepared sap, of .13 gm. in 100 c.c. when enzymes within the expressed sap were permitted to act, and of .20 gm. in 100 c.c. when dilute acid was used. Hydrolysis, therefore, resulted from enzymotic activity and from the use of weak acid. This may be taken to indicate the presence of glucosides in the sap of white snakeroot. It is realized, of course, that there may occur within plants substances which can reduce Fehling's solution without themselves undergoing preliminary hydrolysis, and that substances other than glucosides yield glucose on hydrolysis. Further studies on the nature of the active principle are in progress.

No particular difficulty need be encountered in explaining the excretion of this poisonous principle in the milk, a fact which has long been supported by more or less experimental evidence prior to the present studies. It is a matter of common knowledge that milk acquires tastes and flavors from the feed of the animal. This in itself is proof

*Wiley, H. W., ed. Official and provisional methods of analysis, Association of Official Agricultural Chemists. As compiled by the committee on revision of methods. U. S. Dept. Agr. Bur. Chem. Bul. 107 (rev.), p. 42, 1912.

that foreign substances find entrance into the milk. Furthermore, the medical practitioner well knows that such substances as opium, morphine, and atropin may pass into the mother's milk and act on the nursing child. Not only do organic substances pass into the milk, but many inorganic substances as well,‡ as arsenic, iodine, lead, zinc, mercury, iron, bismuth, and antimony.

MEANS OF PREVENTION AND CURE

Prophylactic or preventive measures, rather than curative measures, are to be employed in dealing with trembles and milksickness, particularly in the case of domestic animals. In districts where the disease was prevalent, early settlers found, by keeping their animals from pasturing upon certain lands or by cutting down the timber and exposing the land to sunlight, that they could avoid the disease. They furthermore found that by plowing dangerous areas and seeding them to cultivated forage plants, they could render them safe for their stock. The employment of either of these preventive measures is in some localities practicable under North Carolina conditions. Where the timbered lands are under the control of timber companies it is not feasible to clear them, and furthermore it would in many places not be advisable to do so because of the value of the timber. If it is possible to clear the land, it should be done since white snakeroot is intolerant to full sunlight. Areas occupied by this weed might in some cases be fenced off, some of them might be mown several times during a growing season, or might even be plowed up. Since the weed is perennial rooted, a single mowing off of the tops, or even a single plowing, would not destroy all of the plants. The destruction of at most a few acres of white snakeroot will in many large pastures render an otherwise dangerous pasture harmless.

Various forms of treatment have been suggested for animals suffering from the disease, but the nature of the changes within the internal organs, as has been described, are such as to extend little hope that beneficial results can follow medication. Among the classes of drugs which veterinarians employ are cathartics such as eserin, internal antiseptics, and nerve stimulants, but without consistent remedial effects. Large doses of sodium bicarbonate are relied upon by others to effect a cure.

Our own experimental work on this phase of the problem has been confined to the use of common salt and baking soda, since the accounts of Moseley (1910) and others suggest that sodium compounds have anti-

‡ *Vide*, Hammarsten and Hedin, a text-book of Physiological Chemistry, 7th edit., 1914, p. 671.

dotal effects. Three animals were employed in this experiment, which was conducted between September 18 and October 20, 1916. The essential facts in this experiment are assembled in Table XIV.

TABLE XIV.—RESULTS OF FEEDING WHITE SNAKEROOT TOGETHER WITH SALT OR SODA TO SHEEP.

Ewe No.	*Initial weight Pounds*	*Placed on feed*	*Date of death*	*Days before death resulted*	*Weight at death Pounds*	*Feed consumed Grain Pounds*	*Weed Pounds*
21	121	Sept. 18	Sept. 29	11	.....	8	5.25
28	96	Sept. 18	Oct. 7	19	73.5	15	10.25
37	118	Oct. 20	Oct. 20	18	78.5	10	6

Ewe 21 consumed 8 ounces of salt and ewe 37 ate 12 ounces during the periods of 11 and 18 days, respectively, in which they were on the experiment. Ewe 28 ate with her feed 30 ounces of baking soda. Salt and soda in these amounts given along with a ration of grain and white snakeroot are therefore without apparent antidotal effect.

The early treatments employed by physicians were drastic, since among them were blood-letting and strong purgatives. Graff (1841) advised the use of calomel, whereas Drake (1841) and Philips (1877) both advised against it. The latter used strychnine apparently with benefit. The allaying of abdominal pain by counter irritation over the stomach was a much used measure. Another favorite measure, which is at present much used, is the giving of liberal quantities of brandy and honey or brandy and milk (Dumm, 1880). Sodium bicarbonate is believed by Walsh (1909) to be efficacious. Medical treatises as recent as that of Hare (1907)* give no specific, but simply state that the treatment is purely symptomatic and consists of the judicious use of stimulants and sedatives as they may be needed.

General Summary

1. A disease of domestic animals commonly called trembles, because trembling is the most prominent symptom, has been the subject of investigation at this Station for two seasons. This disease is also called milksickness since man may contract the disease by the ingestion of milk products from cows affected with trembles. Attention in this investigation has been directed primarily to the etiology, transmission, symptomatology, and pathological anatomy of the disease.

2. A study of the literature on this disease reveals the fact that it has existed in North Carolina since the days of the American Revolution, and that the first published account appeared in 1810. The disease was, no doubt, more commonly present during the early part of the past century than is now the case.

3. Many accounts have been published dealing with the causation of trembles and milksickness. Some of these causes are more or less fanciful, while

*Hare, H. A. A text-book of the practice of medicine, 2d edit., 1907. Philadelphia and New York.

the others may be classified as supporting either (1) the mineral poison theory, (2) the germ or microbic theory, or (3) the poisonous plant theory.

4. The first claim that white snakeroot, Eupatorium urticæfolium, is responsible for the disease seems to have been made as early as 1840. The observations and experiments of several subsequent writers support this claim as do the present experimental studies.

5. There are about forty species of Eupatorium in the southern United States, none of which species except white snakeroot are known to be poisonous, although several species are used medicinally. White snakeroot is commonly present in shady, mountainous situations in western North Carolina, and is distinguishable with difficulty from some of the species of Eupatorium, except by one with experience in identifying plants and by the exercise of close observation.

6. In previous accounts, the symptoms of the disorder appear to have been described in detail only in the case of cattle and of man. The writers have not had occasion to see the disease in cattle or in man and in their studies have employed ewes, lambs, hogs, dogs, guinea pigs, and mice. Trembles was developed in sheep, hogs, and guinea pigs, and the symptoms of the disorder have accordingly been described with considerable fullness and illustrated photographically. The symptoms in sheep and hogs are sufficiently characteristic so that any one who has ever seen an affected animal may be certain of his diagnosis.

7. The disease may appear at any season of the year, but is most prevalent in late summer and autumn especially when other vegetation is scarce because of drought. The disease is frequently fatal in domestic animals while the sequel of milksickness in man, in case of recovery, is lasting debility.

8. The present experiments were conducted at West Raleigh, N. C., about 400 miles distant from the place of collection of the white snakeroot used, and no case of trembles or milksickness had ever appeared in West Raleigh prior to the performance of these feeding tests.

9. During the experimentation, 31 fatal cases of trembles and milksickness have been developed among the 44 ewes and lambs that were employed in some phase of the experimentation involving the feeding of white snakeroot. Two of these lambs contracted genuine cases of milksickness by suckling their mothers, demonstrating that the disease may be transmitted through the milk. This fact has for a long time been a matter of common belief among farmers. Furthermore, animals in lactation, having access to white snakeroot, may be apparently normal yet are capable of transmitting milksickness through their milk.

There was no other contributory cause of death of these 31 animals except in the case of two individuals, in which cases stomach worms may have been, in part, responsible for death.

One of the two hogs employed in the experiment developed a typical case of trembles.

Fifteen of the 29 guinea pigs died from the feeding of white snakeroot or its products.

It is not possible to determine with certainty whether death resulted from the feeding of butter in the case of two of the three mice employed, although it is logical, in view of the experiments with suckling lambs, to believe that the disease may be transmitted through the agency of butter.

No evidence has been secured that the flesh of sheep dead of trembles is capable of transmitting the disease to dogs, although 11 carcasses were eaten by 7 dogs.

Animals appear to differ greatly in their susceptibility to poisoning, since some became affected within a week after feeding on white snakeroot was begun, others only after several weeks, and a few remained unaffected.

10. No detailed studies of the pathological changes accompanying this disease, other than those of Jordan and Harris, have been made prior to the present study. The reports on previous studies seem all to be couched in vague, general terms. The present findings agree essentially with those of Jordan and Harris.

11. No febrile condition is present in affected sheep. The most prominent changes noted in the 22 autopsies on sheep which were performed consist of albuminoid and fatty metamorphoses of the parenchymatous organs. The lesions commonly include petechiation of the epicardium; the presence of a metallic color of the kidneys, which exhibit active and passive congestion and cloudy swelling; a "nutmeg" appearance of the liver which has undergone fatty changes, and is congested so that blood drips freely from the sectioned surface; the occurrence of muco-enteritis of the small intestine; and the presence of a congestive condition of the brain and meninges.

12. All attempts to isolate a specific organism from the internal organs of six sheep, one hog, and one guinea pig were unsuccessful. This is supported indirectly by failure of diseased animals to communicate trembles to healthy ones when they are confined together and fed from the same trough.

13. The active principle is probably glucosidal in nature.

14. The sodium compounds, salt and soda, appear not to possess antidotal effects. In view of the grave cellular changes within the internal organs, there is little hope of the efficacy of medication with domestic animals and preventive rather than curative measures are to be employed.

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EXPLANATION OF PLATES

PLATE 1.

Eupatorium urticæfolium, or white snakeroot, showing the character of the leaves and flowers.

PLATE 2.

FIG. A—Ewe 161 in a characteristic standing posture assumed when the animal is seized with a paroxysm of trembling.

FIG. B—The same animal a few minutes later when the tremors have become more acute. The animal here, as in Fig. A, has spread apart the feet in an effort to remain standing.

PLATE 3.

FIG. C—At this stage of trembling, a few seconds subsequently, the animal is beginning to drop down to a resting posture.

FIG. D—A characteristic resting posture assumed by Ewe 161 after a violent spasm of trembling. Note that the eyes are closed, the ears droop, and the chin is resting upon the ground.

PLATE 4.

FIG. E—Ewe 12 in another resting posture commonly assumed by affected animals. The same evidences of stupor are present, but the head and neck are extended.

FIG. F—A state of coma has set in and the animal (Ewe 12) is no longer able to rise.

PLATE 5.

FIG. G—Lamb 244 in a comatose condition, and her mother (Ewe 171) who is entirely normal.

FIG. H—Guinea pig affected with trembles. This animal is unable to control its movements, and general debility is indicated by the drooping ears and partially closed eyes.

PLATE 6.

FIG. I—A pig at the beginning of trembling.

FIG. J—The tremors have become so violent within a few moments that the animal has settled backward upon her haunches and is squealing.

PLATE 7.

FIG. K—A resting posture assumed by falling forward from the position in Fig. J.

FIG. L—The same animal, prostrate. This position may be taken following Fig. K, or the animal may topple over from a standing posture.

PLATE 8.

FIG. M—Acute parenchymatous nephritis. From Lamb No. 244. *a*, tubule in earlier stage of cloudy swelling; *b*, a tubule in advanced stage of cloudy swelling; *c*, an area infiltrated with round cells and polymorphonuclear leucocytes.

PLATE 9.

FIG. N—Glomerulitis and cloudy swelling of Lamb No. 200. *a*, glomerule; *b*, tubules in state of cloudy swelling.

PLATE 10.

FIG. O—Tube casts from urine of Lamb No. 200 (*a*).

PLATE 1

FIG. A

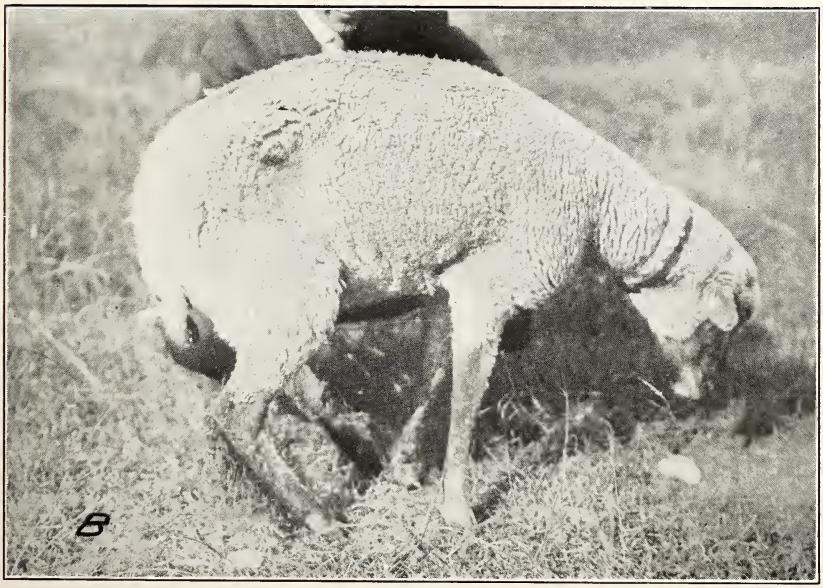

FIG. B

FIG. C

FIG. D

Fig. E

Fig. F

FIG. G

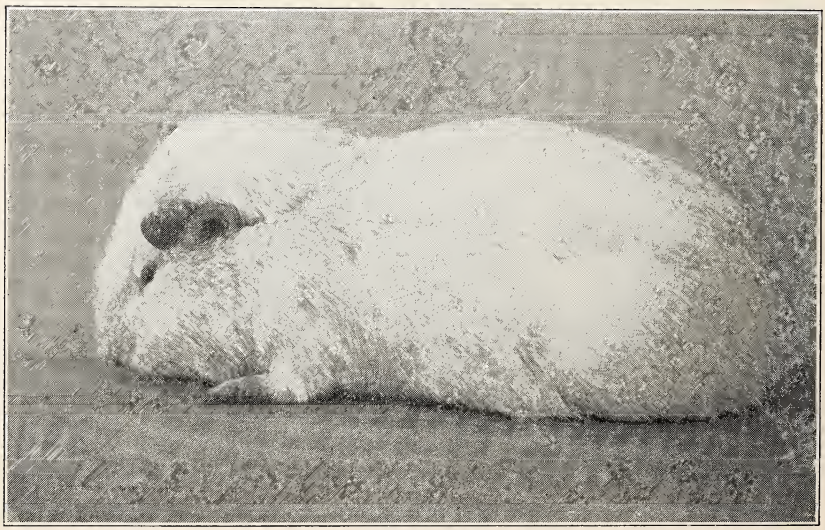

FIG. H

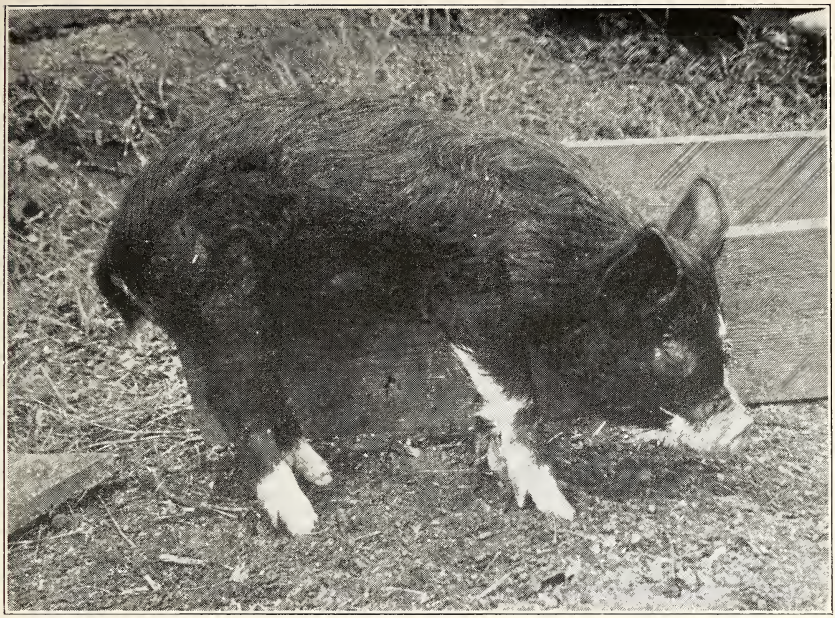

FIG. I

FIG. J

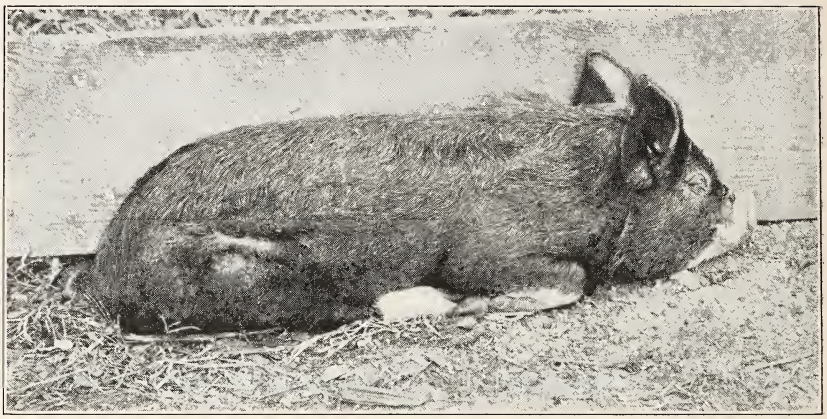

FIG. K

FIG. L

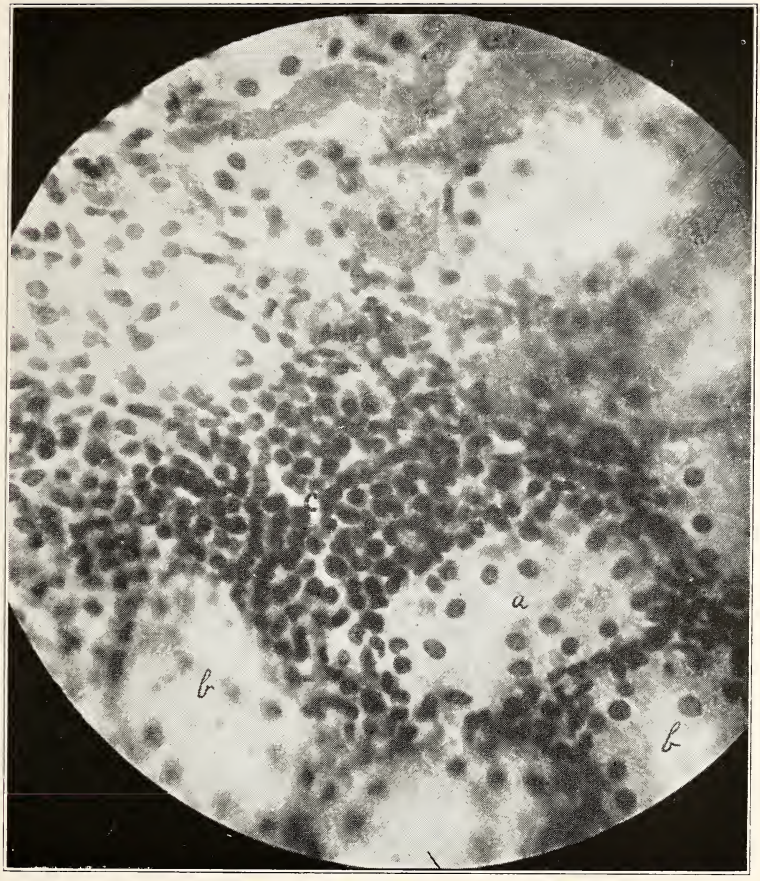

FIG. M

PLATE 9.

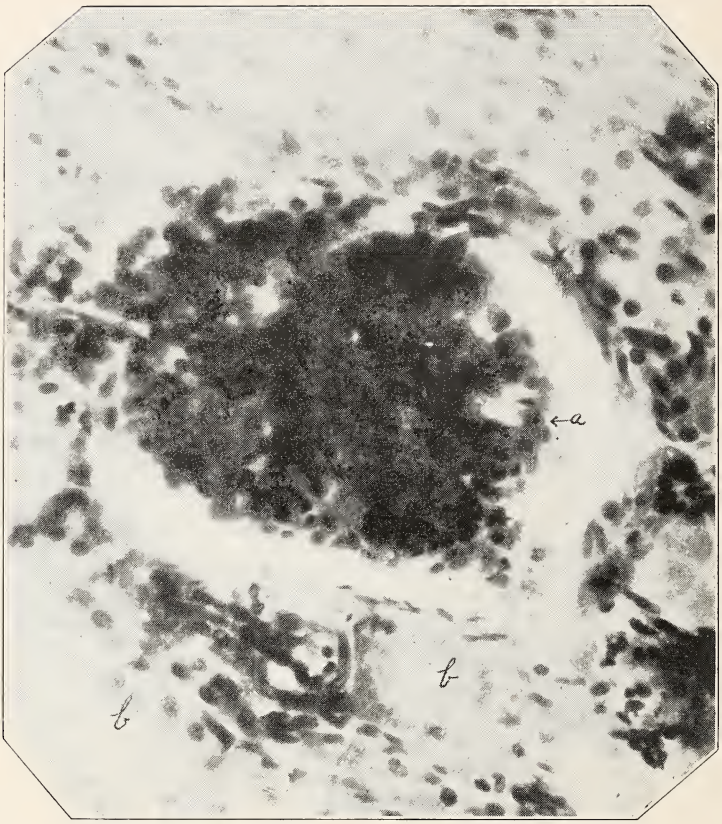

FIG. N

FIG. O

JUNE 1919 TECHNICAL BULLETIN No. 16

CLOVER STEM ROT

F. A. WOLF AND R. O. CROMWELL
Plant Pathology Division

NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION
Conducted Jointly by the
STATE DEPARTMENT OF AGRICULTURE
and the
NORTH CAROLINA STATE COLLEGE OF
AGRICULTURE AND ENGINEERING

RALEIGH AND WEST RALEIGH

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CLOVER STEM ROT[1]

By
FREDERICK A. WOLF AND R. O. CROMWELL

INTRODUCTION[2]

There has been present for several years in North Carolina a stem rot disease of crimson clover, Trifolium incarnatum. This disease has attracted attention because it results in the death of all plants in well-defined areas, involving in some instances, spots of considerable extent. Numerous inquiries as to the cause of this condition have been received during the past few years at the North Carolina Experiment Station and have led to an investigation of the nature of this stem rot disease. Furthermore, the growing importance of crimson clover as a cover crop and as an invaluable means of increasing and maintaining soil fertility makes it desirable to circulate the facts established by this investigation as widely as possible. It seems advisable, therefore, to present at this time, data bearing upon the history and distribution of the disease, on the relationship and life history of the causal organism, and on methods for the prevention and control of its ravages.

Historical

The disease in epidemic form has long been known in Europe and was observed as early as 1857 (14, 15, and 18) near Beberbeck, in the province of Hesse, Germany. Here it appeared in a field seeded with a mixture of red clover, Trifolium pratense and white clover, Trifolium repens, and was noted to be more destructive during the moist winter weather than during the preceding dry autumn. In 1870 it was first noted in Denmark and by 1878 it had spread to Sweden.

Two extensive accounts of this disease in Europe have appeared, one by Rehm (18) in 1872 and the other by Eriksson (6) in 1880. The first of these deals primarily with the morphology and development of the causal organism which is identified as Peziza ciborioides Fr. It also contains suggestions for the control of the disease and a record of observations upon the host species which were found to include red clover, white clover, crimson clover, and alsike clover, Trifolium hybridum. Among the other leguminous plants which were exposed to infection, but which remained healthy were alfalfa, Medicago sativa, sainfoin, Medicago falcata, black medic, Medicago lupulina, Onobrychis sativa, Ornithopus sativa, white sweet clover, Melilotus alba, and blue sweet clover, Melilotus caerulea. The other account deals with the distribution of stem rot and with the life history and nomenclature of the

[1] Submitted for publication December 10, 1917.
[2] The junior author is now at the Iowa Agricultural Experiment Station, Ames, Iowa.

fungus which is designated, Sclerotinia trifoliorum Erik. In 1890 (19) the disease was reported as more destructive to Medicago lupulina in Denmark than to species of Trifolium. Subsequent accounts by European investigators deal primarily with experimental procedures looking toward the control of the disease.

Stem rot has not only been prevalent in continental Europe, for a long time, but it very probably was the cause of lands becoming "sick of red clover," hence the name clover-sickness in the British Isles, as early as the early part of the nineteenth century. Investigations on clover sickness were begun at the Rothamsted Experiment Station, England, in 1849 (12) but the relation of the disease to the fungus Sclerotinia trifoliorum was not established until 1897 (3). English writers had previously expressed a variety of views in regard to the cause of clover sickness. Carruthers (3) at this time ascribed the disease to the fungus in question and suggested methods for its control.

The first observation of the occurrence of clover stem rot within the United States appears to have been made in 1890 in Delaware (2). While the disease was during subsequent years noted in several other States, it appears not to have been sufficiently destructive to incite investigation. In 1914-1915, however, it was reported by Gilbert and Myer (10) to be productive of serious damage to young alfalfa plants in Kentucky. This report and a subsequent one (11) constitute the only American accounts which indicate any considerable study of the disease.

Distribution of the Disease

As indicated above, the disease is known to occur abroad in Germany, Denmark, Sweden, and England, and in America within Delaware and Kentucky. It has furthermore been recorded from Canada, New York, New Jersey, Virginia, Indiana, Oregon, and North and South Carolina. Its prevalence in these states indicates that it very probably occurs in other of the states where clover is grown. Its distribution within North Carolina is not completely known, but since clover is generally grown throughout the State and since the points from which collections of diseased material have been made are quite widely separated, it is believed that the disease is generally prevalent. As indicated by these collections the disease is known to occur within thirteen counties, namely: Alamance, Chatham, Columbus, Edgecombe, Forsyth, Granville, Halifax, Lincoln, Mecklenburg, Moore, Orange, Rowan, and Wake.

Host Plants

The disease has been shown by European writers to attack red clover, white clover, crimson clover, alsike clover, sainfoin and alfalfa. To this list Gilbert and Myer (10) have added spotted spurge, Euphorbia macu-

lata. Frank (7) observed a sclerotial disease of peanuts of whose identity he could not be certain since he did not have the apothecial stage, but he may have been dealing with the same organism.

Names of the Disease

As is the case with many plant diseases, various common names have been applied to this disease, although the name stem rot seems to be most appropriate. Among other names which have been employed are clover rot, wilt, and root rot. In England the name clover sickness has long been employed and other European accounts make use of the names Sclerotium rot, clover rot (Kleefaule), and clover canker (Kleekrebs).

Description of Clover Stem Rot

Stem rot on crimson clover can first be noticed in the fall when the plants are still small. It continues to spread, however, when weather conditions permit, throughout the winter months and is destructive until the time when unaffected plants are mature. The first evidence of the presence of the disease is manifested by a wilting of the stem and leaves. These portions then turn yellowish, rather quickly succumb and become brown (Plate 3, Fig. 1). Closer examination discloses the fact that the stems near the base of the stool or at the ground level are involved in decay, which begins as a slight discoloration and proceeds until the stems have rotted off. At this time a dense, white, mold-like growth is prominently present at the base of affected stems. In the presence of a suitable supply of moisture this fungous growth becomes more profuse and within a few days, compact masses of hyphae will have formed on the surface of the decaying stems (Plate 3, Fig. 1). These masses soon become black in color and of a cartilaginous consistency and are the sclerotial stage of the causal organism.

These black sclerotia are sometimes as large as a pea and their presence can be used as an aid in a field diagnosis of the disease. With the maturing of these sclerotia and the simultaneous disintegration of the stems, the sclerotia remain scattered over the soil where the plant has been. Meanwhile, the roots also are involved in decay and the sclerotia which are formed as the tissues become decomposed, remain in the soil. Since the disease spreads outward from a center of infection, plants in all stages of the disease may be found in any one spot. When the diseased areas are large the centers may be entirely bare or there may remain the debris of the badly decayed stems. The stand of clover, in case plants die in localized areas, is thus rendered not uniform or when the centers of infection are numerous and extremely favorable conditions prevail, the stand may be rather uniformly destroyed.

Etiology

Clover stem rot is caused by a discomycetous fungus, Sclerotinia trifoliorum Erik. This organism is identical with the one which was first illustrated by Hoffmann (13) in 1863, but to which he applied the name Peziza ciborioides Fries. Furthermore, it is the same as the one which is so fully described by Rehm (18) and which he designated as Peziza ciborioides Fries. The organism which was originally identified as Peziza ciborioides by Fries (9) in his Systema Mycologicum, as has been pointed out by Eriksson (6), is entirely different from the clover stem rot fungus. In the first place, Fries makes no mention in his description of Peziza ciborioides of sclerotia, structures which could not have escaped his notice had he been working with the fungus on clover. Then, too, he states that the fungus grows early in spring upon stems in moist places and heathes, whereas the clover rot fungus appears in Sweden during the fall upon the collar of clover plants. Both the time of appearance and the habitat of the fungi, therefore, fail to accord. It was for these reasons that Eriksson regarded Peziza ciborioides Fries as applying to a form entirely distinct from the clover stem rot organism.

Güssow (12) has suggested that the combination Sclerotinia ciborioides Rehm is the most tenable name. In the light of the fact, however, that Rehm (18) misidentified Fries' species there appears to be little reason for retaining the specific name ciborioides, when the proper generic name Sclerotinia instead of Peziza is employed.

Morphology of Sclerotinia Trifoliorum

Although several careful investigations on the morphology of the stem rot fungus have been reported, this phase of the problem is given attention at this time because of certain statements in recent bulletins and text-books bearing on the relationship of Sclerotinia trifoliorum and Sclerotinia libertiana. In a bulletin dealing with wilt of alfalfa in New York, for example, Stewart, French and Wilson (22) state "that the fungus causing the disease is supposed to be the Sclerotinia trifoliorum Erik, given in all text-books on plant diseases as the cause of a stem rot of clover and which is said to attack also alfalfa. However, Prof. R. E. Smith, to whom specimens were sent, reported (20) that "the sclerotia were entirely similar to those of Sclerotinia libertiana and that they produce a Peziza form which leaves no doubt that the fungus really is Sclerotinia libertiana." Duggar (5) states that some regard the clover stem rot fungus as identical with Sclerotinia libertiana. Stevens (23) states that they are "by some regarded as identical; sufficient evidence has, however, not been adduced to prove them the same." More recently Smith (21), in an investigation of cottony rot of lemons in California, caused by Sclerotinia libertiana, has noted that the same

organism attacks alfalfa and vetch. It seems desirable, therefore, that a comparative study of Sclerotinia trifoliorum and S. libertiana be made to establish their relationship to each other. They were accordingly isolated from crimson clover and from lettuce respectively and maintained in culture under observation for a considerable period.

The mycelium or vegetative body of the clover stem rot fungus appears under no conditions, except in the formation of sclerotia, to produce an abundant aerial growth on the surface of stems. It is then not loose and cottony, as in the case of lettuce drop fungus, in which there is a profuse mycelium, especially under conditions of high relative humidity. This is in accord with observations by Gilbert and Meyer (10) on Sclerotinia trifoliorum and Stevens and Hall (24) on Sclerotinia libertiana. Furthermore, constant differences in mycelial development are apparent in culture. On steamed cornmeal or potato agar, media noted to favor rapid growth of both organisms, S. libertiana makes the more luxuriant, rapid growth, a difference which persists even after sclerotial formation has been completed. Even though there is considerable variation in diameter of the hyphae, with an overlapping of extremes, the lettuce drop fungus possesses the larger, coarser mycelial threads. Comparative measurements of the younger growing tips, as shown in Plate 1, Fig. 1, indicate that the relative diameters are approximately in the proportion of 2 to 3.

It does not appear to be possible to differentiate between the peculiar processes termed attachments, which have been described in previous accounts and which develop when contact between hyphal tips and wall of the culture flasks or Petri dishes is effected. In the case of each organism, the hyphae become flattened, septate, profusely branched and interlaced resulting in the formation of dark masses which adhere to the glass surfaces.

The sclerotia of both are variable in shape, in that they are spherical, cylindrical, flattened or irregular, and in size which ranges in the case of S. trifoliorum from .3 to 10 mm. and to as large as 20 mm. in S. libertiana. In general, the latter is considerably larger as indicated in Plate 2, Fig. 2. No differences in development or structure were noted, however. From 2 to 3 weeks are required for their formation. They begin as dense, floccose, white mycelial masses. After a few days the masses have increased in size, become compact and of a cartilaginous consistency. At this stage they are white to pale cream-colored, which color persists within although the exterior rapidly changes to an inky black. In culture on flasks of steamed corn meal, very abundant sclerotial formation results, forming in some instances, a sclerotial crust over the entire surface in the case of the clover stem rot organism, whereas the sclerotia remain for the most part separated in S. libertiana.

No observable differences were noted in the size and manner of production of the apparently functionless microconidia. These structures are small, spherical bodies, 2 to 4 mikra in diameter, which are abstricted in acropetal succession from flask-shaped cells. These cells may appear as lateral or terminal branches from the vegetative hyphae, Plate 1, Fig. 2, or from the germ tubes produced in the germination of the ascospores. Microconidia may form in conspicuous, grayish, mealy patches on the surface of the mycelium in culture. They have not been observed to germinate except by the formation of a hypha 2 or 3 mikra long, nor has it been possible to bring about infections with them. This accords with the results by others, among whom are Coleman (4). During April, 1916, twenty crimson clover plants were sprayed with a suspension of microconidia from S. trifoliorum, were then covered to conserve moisture but no sign of infection was subsequently noted.

The macroscopic characters of the apothecia cannot be employed in differentiating the two forms. The stipe and disc are yellowish brown in color. The stipes are variable in length, depending upon the depth below the surface of the soil to which the sclerotia are buried. In extreme cases their length varies from 3 to 30 mm. and their thickness from 1 to 2 mm. The discs are at first deep cup-shaped, but expand to a flat disc, 3 to 10 m.m. in diameter, the margin of which may become reflexed and fissured, Plate 1, Fig. 4. Apothecia of both species have been secured by the writers by burying selerotia from 2 to 9 months in moist sand in flower pots. Sclerotia of S. trifoliorum which had been matured in culture in July, 1910, were planted during September and they had developed fruiting discs by December, Plate 3, Fig. 2. Comparative measurements of asci and ascospores from these apothecia, as indicated in text, Plate 1, Fig. 3, show that the asci and ascospores of S. trifoliorum are very manifestly larger than those of S. libertiana which facts accord with observations of other investigators. These data are assembled in the following tabulation:

Sclerotinia Trifoliorum			Sclerotinia Libertiana		
Author	Size of Asci	Size of Ascospores	Author	Size of Asci	Size of Ascospores
Rehm	160x10*	15-17x8-10*	Saccardo ..	130-135x 8-10*	9-13x4-6.6*
Eriksson	180x12*	14-18x8*			
Kuhn	160-180x14*	16-20x8-10*	Stevens & Hall	82-2(?)	8.7-11.6x5.8*
Present writers...	140-160 8-11*	12-14x8*	Present writers...	95-120x 8-9*	7-9x6*

*Mikra.

Life History of the Causal Organism

The life cycle of the clover stem rot fungus is relatively simple since it possesses only one functional type of spore. It lives for the greater part of the year as a saprophyte and can maintain itself in the soil upon decaying plant tissues from one year until the next. On the basis of difference in appearance and function, the fungus may be regarded as possessing three stages. Under normal conditions the first or vegetative stage is present during late fall, winter, and early spring, within the clover plants causing their death. Invasion of the tissues begins at the collar, near the ground level, and extends upward and downward from this point of attack. During the same period the fungus continues its vegetative growth as a saprophyte in plants which it has killed. As the tissues are disintegrated the fungus appears at the surface of the decaying parts and becomes massed together in compact black sclerotia, the second stage. These sclerotia then remain dormant on the surface of the soil or within the soil in the spots left bare by the destruction of the clover. Since these sclerotia require only two or three weeks to mature they are being formed practically throughout the entire growing period of the clover crop. These sclerotia, which contain a reserve of nutriment, remain dormant and serve to carry the fungus over the summer season, or until opportune conditions for their growth again prevail. During the fall and early winter these sclerotia germinate by the formation of slender, yellowish-brown stalks. The distal ends of these stalks expand into the disc-shaped fruit bodies, which with the stalks constitute the apothecia, the third stage. From one to a half dozen apothecia are developed from each sclerotium, depending upon the size of the sclerotium. The upper or inner surface of these discs is lined with a layer of closely aggregated, elongated sacs, or asci, interspersed with the paraphyses. Rehm (18) has estimated that there are approximately 5,000 sacs in one square millimeter of surface, each of which bears at maturity eight ascospores. These ascospores are forcibly discharged, often in such numbers as to appear like small clouds of dust. They may then be carried by the wind to a moist surface and there germinate at once by the formation of a hypha. This hypha becomes, as growth proceeds, the vegetative mycelium, thus completing the cycle of development.

Whether these ascospores directly infect clover is not known, aside from the experimental work of Rehm (18) and Coleman (4). The former suspended mature fruit bodies over healthy plants and within 6 to 8 days the mycelium was present within the leaf blades, the plants subsequently collapsed, and sclerotia were formed in due time. He did not determine the mode of entrance of the germ tubes, but regarded it as probable that they entered through the stomates. The latter reported that young clover plants only can be readily infected by ascospores,

although under favorable conditions older plants were in a few instances attacked. His investigations furthermore led him to assert that infection does not take place through the stomates, but by penetration of the epidermal cell walls. The results of direct infection of lettuce by ascospores of Sclerotinia libertiana led Stevens and Hall (24) to conclude that it seldom, if ever, occurs, and that the fungus becomes parasitic only after it has maintained itself for a time, as a vigorous saprophyte. Because of the fact that infection begin on the stems at or near the ground level in the case of stem rot of clover, it is believed that the vegetative mycelium is responsible for the disease and that little disease results naturally by direct infection with ascospores.

Infection Experiments

Several series of artificial inoculation tests have been made during the past two years. These involved plants of crimson clover, red clover, and lettuce grown within the greenhouse in flats or in beds, and crimson clover, hairy vetch, Vicia villosa, and lettuce grown under field conditions. Inoculation in the greenhouse was accomplished by introducing the appropriate organism from cultures on steamed rice or steamed corn meal or from diseased plant parts into the soil near the collar of the plants. Wilting was apparent within 8 to 10 days in the case of lettuce, crimson clover, or red clover, when either Sclerotinia trifoliorum or S. libertiana were employed. Practically all of the inoculated plants succumbed, irrespective of whether the inoculum consisted of pure cultures or of decaying plant tissues.

During April, 1917, plants of crimson clover and vetch five to eight inches in height were inoculated in the field by parting the stems and placing at the center of the plant fragments of lettuce affected with drop, S. libertiana. The plants thus inoculated were then lightly covered for 36 hours with a newspaper weighted at the corners. Five days after inoculation many of the younger stems near the center of the rosette were dead and their tissues involved in decay. The copious superficial mycelial growth was like that of the lettuce drop organism. Within twelve days even the larger stems had begun to wilt. Stem rot had never been present in this field and only the inoculated plants were affected. Furthermore, lettuce plants in another field were inoculated on the same day by inserting diseased lettuce leaves into the heads. These plants were in an advanced stage of drop a week later.

During November, 1917, crimson clover in the field was inoculated by placing in the soil pure cultures on corn meal of S. trifoliorum and of S. libertiana. Four weeks later circular areas eight to ten inches in diameter in which all of the plants were dead, had formed around the

place of inoculations with each of the organisms. Lettuce plants, furthermore, became affected when diseased clover plants were transplanted beside them. These reciprocal inoculations leave no doubt that both clover and lettuce may be attacked by either S. trifoliorum or S. libertiana. Smith's (21) observations on the cause of cottony rot of lemons are of interest in this connection since he states that their decay is due to S. libertiana, although S. trifoliorum is able to develop on artificially inoculated lemons and may cause some of the infection. He also points out that alfalfa and vetch when grown as cover crops in lemon groves are attacked by S. libertiana. The confusion which has existed in the literature dealing with the identity and relationship of S. trifoliorum and S. libertiana is, therefore, clarified by these reciprocal inoculations which are in part a confirmation of studies and observations by Smith (21).

Means of Spread of Stem Rot

It seems highly probable that stem rot of clover was introduced into America from Europe, but the method of its introduction, together with the means for its spread into new localities each year, have remained more or less problematical. Eriksson (6) states that the fungus undoubtedly overwinters as hyphae adhering to the seeds and not as sclerotia or spores and that the disease is spread by this means.

Coleman (4) suggests that sclerotia mixed with the seed are a probable means of the distribution, although spores adhering to the seeds are also a possible means. Observations on this point, first made during the fall of 1914, by Prof. H. R. Fulton, then Plant Pathologist for the North Carolina Experiment Station, show that sclerotia are present in commercial crimson clover seed. He states:* "I received from county agents some six or eight samples of seed. Two of these, I distinctly remember, showed the contamination with sclerotia." If seed were harvested from affected fields, sclerotia would almost certainly be mixed with seed (Plate 2, Fig. 3), and would remain with them even though the seed were very carefully cleaned. Seed contaminated with sclerotia are, therefore, believed to account for the introduction and presence of stem rot of clover.

Numerous possibilities might be suggested to account for the local distribution of the disease. The fungus is known to spread through the soil along the margin of the diseased areas. Further, the sclerotia which normally remain dormant for a time, even though favorable conditions for their germination may obtain and which may retain vitality for at least two and one-half years under laboratory conditions and one and one-half years in the soil (18) may aid in its spread. They may be dis-

*From a letter dated October 25, 1917.

tributed by the implements used in cultivation, by the use of soil in inoculating with the nodule forming organism, by rains, or by being harvested with the hay crop. If this hay is fed to stock the possibility exists of the return of these sclerotia to the fields through the manure.

The violent discharge of ascospores from the mature apothecia and the carriage of these spores by the air currents may also be taken into account in the local spread for short distances of the stem rot fungus.

Methods of Control

A very considerable body of data and observations bearing on methods of control have been presented in published accounts of stem rot. Much of the experimental work is of value, however, only inasmuch as it indicates methods which cannot be employed with success. In the light of the facts which have been presented relative to the life history of the causal fungus, some of these experimental results are to be anticipated. This may be instanced by the work with fertilizers and manures at the Rothamsted Experiment Station (16) which was based on the assumption that "clover sickness" is due to unfavorable soil conditions. No appreciable differences in treated and untreated plots were noted, results in agreement with those of Rehm (18) and others who have performed less extensive tests. Among the different fertilizers which have been applied are guano, barnyard manure, compost, bone meal, woodashes, gypsum, and lime. In the Essex experiments (1), where ground limestone was employed, clover remained free from disease. Causes other than the use of lime are believed to have been operative in this case, since these results do not accord with those just presented nor with the more recent ones of Coleman (4).

Among the cultural practices which have been noted to be of benefit by Freckmann (8) and Gilbert and Myer (10) are deep plowing. This was suggested from experiments by Rehm (18) in which sclerotia were buried at different depths in garden loam. No apothecia were developed when sclerotia were covered as deep as eight cm., about 3 inches. Rehm further pointed out that buried sclerotia were subject to destruction by earthworms, wireworms, millipeds, and mites. During the season of 1917 the sclerotia which were covered with sand in the studies on apothecial development were, in several series, noted to be completely devoured by fungus gnats, Mycetophilidae. The burial of sclerotia particularly when the soil is kept moist favors their decay from natural causes. Complete decay of the sclerotia of Sclerotinia trifoliorum was observed by the writers to be accomplished within two months. Stevens and Hall (24) have reported that under natural conditions the number of sclerotia of S. libertiana is greatly reduced by decay.

Precaution should be exercised both in the saving of seed from affected crimson clover fields and the planting of such seed because of its contamination with sclerotia. To guard against the introduction of stem rot into new fields or new localites, seed should be sampled and sent to a seed testing laboratory in advance of purchase. The introduction of the disease through manure from stock fed on hay from affected fields is also to be guarded against.

It is known that not all host species are equally subject to attack by S. trifoliorum, but whether or not any one of these species possesses marked varietal differences in susceptibility is not known. No experimental work appears to have been done on selection for disease resistance and the only observation that has come to our attention that such differences exist is by Nilsson-Ehle (17) who records that Swedish red clover of the variety serotinum is more resistant than exogenous strains.

In fields badly infested no measures can be relied upon to be effective other than the adoption of a proper rotation system in which clovers are not grown for a period of three or four years. Definite data are wanting on the length of time which the stem rot organism can live saprophytically in the soil, but it is logical to assume that it would no longer be present or the infective material would at least be greatly reduced in amount within a lapse of three or four years. Cowpeas and soybeans which are not subject to attack by Sclerotinia trifoliorum may well be used as a leguminous crop in such a system of rotation and winter oats and rye can be employed as winter cover crops.

Summary

1. Stem rot of clover is a fungous disease quite widely prevalent upon crimson clover within North Carolina.

2. Other kinds of legumes as red clover, white clover, alsike clover and alfalfa are subject to the same disease.

3. Stem rot occurs in several states and has been known in America since 1890. It was present in England over one hundred years ago, where it caused failures of red clover and was popularly called clover sickness. The disease was first reported in continental Europe in 1857.

4. The disease is prevalent from October to March and may be recognized by (1) a sudden wilting and death of plants in spots; (2) a rotting off or decay of the stems near the surface of the ground; (3) the presence of black sclerotia on the decaying stems.

5. The causal organism was first described in 1863 as Peziza ciborioides Fries. Since this was a mistaken identification it was in 1880 given the name Sclerotinia trifoliorum Erik, which name has been employed in the present account.

6. The fungus may be said to possess in its life cycle three stages, a vegetative or mycelial stage, a sclerotial stage, and an apothecial or ascogenous stage.

7. A study has been made of the development of S. trifoliorum from diseased crimson clover in comparison with S. libertiana from lettuce affected with drop. The two differ in luxuriance of mycelial growth, size of hyphae, size of sclerotia, and size of asci and ascospores.

8. In the infection experiments S. trifoliorum has been successfully inoculated into lettuce and crimson clover and S. libertiana into lettuce, crimson clover, and vetch.

9. The comparative morphological studies indicate that S. trifoliorum and S. libertiana are distinct species. Furthermore, the reciprocal inoculations clarify existing accounts of the identity and relationship of the two organisms.

10. The feature of most economic importance in the life history of the stem rot fungus is that the sclerotia may be mixed with the seed at time of harvest. The planting of such contaminated seed then insures the spread of the disease to new localities. Other agencies as implements, soil, and hay from infected fields may serve as a means of spread.

11. The sclerotia which remain dormant in infested soils constitute the means of keeping the organism alive where the disease has once appeared. Burial by deep plowing prevents their germination and thus prevents the spread of stem rot. Many sclerotia decay from natural causes and many are destroyed by insects.

12. Introduction of the disease into fields where it is not yet present should be prevented by avoidance of contaminated seed, by the exercise of care when soil is used to inoculate new fields with the legume nodule forming bacteria, and by not returning manure to clover fields when hay from infested fields has been fed.

13. The adoption of a system of crop rotation is the only reliable means of control for infested fields. Cowpeas and soybeans can be used in this rotation system to increase and maintain soil fertility, and winter oats and rye can serve as cover crops.

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EXPLANATION OF ILLUSTRATIONS

PLATE 1, FIG. 1—(a) Hypha of Sclerotinia libertiana and (b) of S. trifoliorum from the margin of colonies on potato agar showing relative size of the two species.

PLATE 1, FIG. 2—Microconidia (a) of Sclerotinia libertiana and (b) of S. trifoliorum borne on hyphal branches in old cultures.

PLATE 1, FIG. 3—Asci and ascospores (a) of Sclerotinia trifoliorum and (b) of S. libertiana, drawn with the same magnification.

PLATE 1, FIG. 4—Apothecia of S. trifoliorum developed from sclerotia.

PLATE 2, FIG. 1—Normal plant of crimson clover of the same age as the diseased ones shown in Plate 3.

PLATE 2, FIG. 2—Sclerotia (a) of Sclerotinia trifoliorum and (b) of S. libertiana, natural size.

PLATE 2, FIG. 3—Crimson clover seed contaminated with small sclerotia, which can scarcely be distinguished from the seed.

PLATE 3, FIG. 1—Plants of crimson clover affected with stem rot, S. triofoliorum, showing several stages of the disease. Sclerotia have formed on the stems as indicated by the direction of the arrows.

PLATE 3, FIG. 2—Apothecia of S. trifoliorum developed from sclerotia grown in pure culture and buried in sand.

PLATE 1

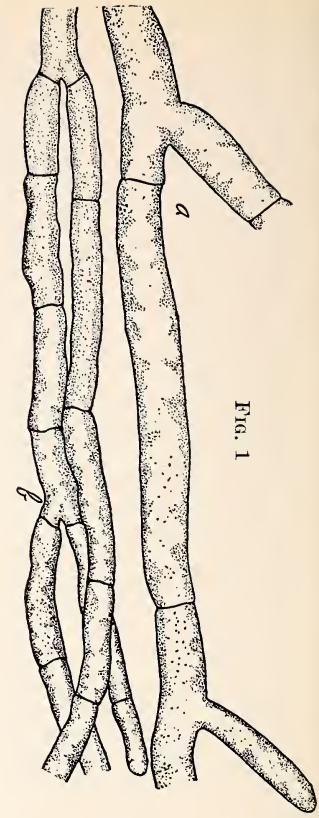

Fig. 1

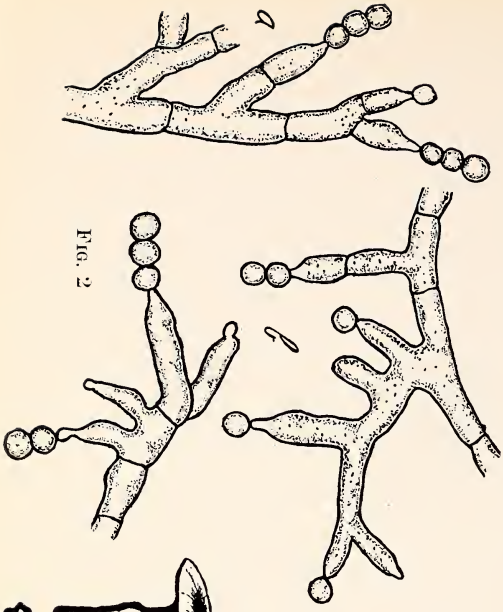

Fig. 2

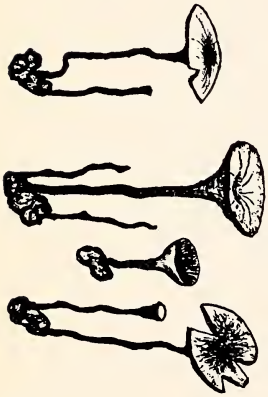

Fig. 4

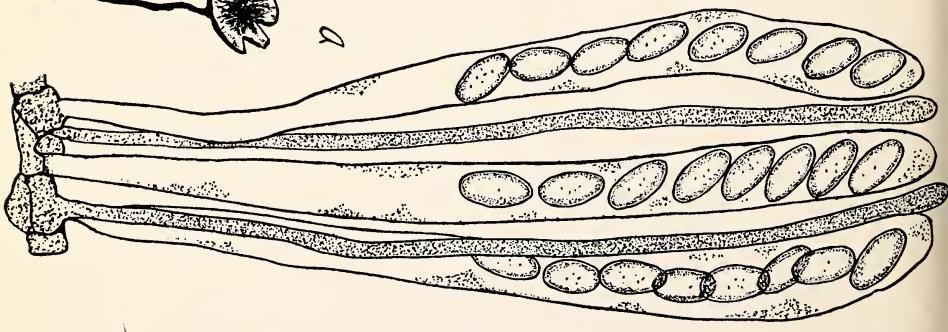

Fig. 3

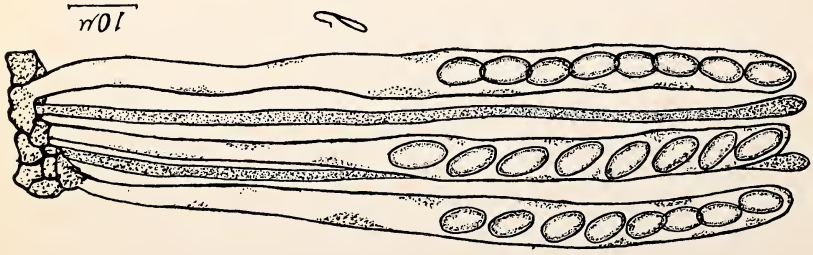

FIG. 1

FIG. 2

FIG. 3

PLATE 3

FIG. 1

FIG. 2